FOSTER WHEELER ENVIRONMENTAL CORPORATION

FINAL

REMEDIAL INVESTIGATION REPORT FOR OPERABLE UNIT 2: POTENTIAL ON-SITE CONTAMINANT SOURCE AREAS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, California 91109

VOLUME I

FINAL

REMEDIAL INVESTIGATION REPORT

FOR

OPERABLE UNIT 2: POTENTIAL ON-SITE CONTAMINANT SOURCE AREAS

AT THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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4800 Oak Grove Drive
Pasadena, California 91109

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LIST OF ACRONYMS AND ABBREVIATIONS

ADD	Average daily dose
AF	Soil to skin absorption fraction
Ag	Silver
ARAR	Applicable or Relevant and Appropriate Requirements
As	Arsenic
ASTM	American Society for Testing Materials
AT	Averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
Ba	Barium
BA	Bioavailability
Be	Beryllium
bgs	Below ground surface
BTEX	Benzene, toluene, ethylbenzene and total xylene
BTX	Benzene, toluene, and xylene
BW	Body weight
C_{max}	Maximum detected concentration
C_{mouse}	Estimated concentration in deer mouse tissue
C_s	Chemical concentrations in soil corresponding to the PRG
C_v	Vapor concentration
Ca	Calcium
CalEPA	California Environmental Protection Agency (In this document, the term is limited to the DTSC and the RWQCB)
CalTech	California Institute of Technology
CCl_4	Carbon tetrachloride
Cd	Cadmium
CDF&G	California Department of Fish and Game
CDHS	California Department of Health Services
CDI	Chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
$CHCl_3$	Chloroform
CLP	Contract Laboratory Program
CN^-	Cyanide
Co	Cobalt
COEHHA	California Office of Environmental Health Hazard Assessment
COPC	Constituents of potential concern
Cr	Chromium
Cr(VI)	Hexavalent chromium
CSF	Cancer slope factor
Cu	Copper
DCA	Dichloroethane
DCE	Dichloroethene

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

DP	Discharge point
DTSC	California State Department of Toxic Substances Control
DW	Dry well
d/y	Days per year
EB	Equipment blank
ED	Exposure duration
EF	Exposure frequence
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
ERA	Ecological risk assessment
ERG	Eastern Research Group
ESI	Expanded site inspection
Fe	Iron
FID	Flame-ionization detector
FIR	Food intake rate
Freon 113	Trichlorotrifluoroethane
FS	Feasibility study
FSAP	Field Sampling and Analysis Plan
ft, ft^2, ft^3	Foot or feet, square feet, cubic feet
FWENC	Foster Wheeler Environmental Corporation
GALCIT	Gugenhiem Aeronautical Laboratory, California Institute of Technology
GC	Gas chromatograph
H'	Henry's Law Constant
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Table
Hg	Mercury
HHRA	Human health risk assessment
HI	Hazard index
HQ	Hazard quotient
HRS	Hazard Ranking System
IAEA	International Atomic Energy Agency
ICP	Ion-coupled plasma
ID	Inside diameter
IF_S	Soil ingestion fraction
IR	Intake rate
IRIS	Integrated Risk Information System
JPL	Jet Propulsion Laboratory
K_d	Soil-water distribution coefficient
kg	Kilogram
kg/day	Kilograms per day
LADD	Lifetime average daily dose

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

lb	Pound
LOAEL	Lowest-observed-adverse-effects-level
M50	Trichloroethane
MEK	Methyl ethyl ketone
mg/d	Milligrams per day
mg/day	Milligrams per day
mg/kg	Milligrams per kilogram
mg/kg-day	Milligrams of chemical per kilogram of body weight per day
mg/L	Milligrams per liter
Mn	Manganese
Mo	Molybdenum
MW	Monitoring well
N	Nitrogen
NA	Not analyzed or not applicable
NASA	National Aeronautics and Space Administration
NCA	National Coffee Association
NCRP	National Council on Radiation Protection and Measurements
ND	Not detected
Ni	Nickel
NO_3^-	Nitrate
NOAEL	No-observable-adverse-effects-level
NPL	National Priorities List
NR	Not regulated
NTP	National Toxicology Program
OCDD	Octachlorodibenzo-p-dioxin
OD	Outside diameter
OU-1	Operable Unit 1 (On-site Groundwater Investigation)
OU-2	Operable Unit 2 (On-site Contaminant Source Investigation)
OU-3	Operable Unit 3 (Off-site Groundwater Investigation)
OUM	Operable unit manager
OVA	Organic vapor analyzer
PA	Preliminary assessment
Pb	Lead
PAHs	Polynuclear aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PCE	Perchloroethene (tetrachloroethene)
pCi	Picocurie
PEA	Preliminary Endangerment Assessment Guidance Manual
PID	Photo-ionization detector
PRG	Preliminary remediation goal
PVC	Polyvinyl chloride

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

QA/QC	Quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	Quality control
RA	Risk assessment
RAP	Remedial action plan
RCRA	Resource Conservation and Recovery Act
RF	Response factor
RfD	Reference dose
RFI	Remedial field investigation
RI	Remedial investigation
RI/FS	Remedial investigation/feasibility study
ROD	Record of decision
RPD	Relative percent difference
RWQCB	California Regional Water Quality Control Board, Los Angeles Region
SARA	Superfund Amendments and Reauthorization Act
Sb	Antimony
Se	Selenium
SI	Site inspection
Sr	Strontium
SVOCs	Semi-volatile organic compounds
TCA	Trichloroethane
TCDD	Tetrachlorodibenzo-p-dioxin
TCE	Trichloroethene
TCLP	Toxicity characteristic leachate potential
TEF	Toxicity equivalency factor
TEG	Transglobal Environmental Geochemistry
TEQ	Toxic equivalent
TF	Food-to-muscle transfer factor
Tl	Thallium
TPH	Total petroleum hydrocarbons
TRPH	Total recoverable petroleum hydrocarbons
TRV	Toxicity reference value
μg/kg	Micrograms per kilogram
μg/L	Micrograms per liter
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
V	Vanadium
VOCs	Volatile organic compounds
WP	Waste pit
Zn	Zinc

EXECUTIVE SUMMARY

Presented in this report are the results of the Remedial Investigation (RI) for Operable Unit 2 (OU-2), Potential On-Site Contaminant Source Areas, at the Jet Propulsion Laboratory (JPL) in Pasadena, California. In October 1992, JPL was placed on the National Priorities List (NPL) and subsequently became subject to the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, hereafter jointly referred to as CERCLA. This RI was completed at the JPL site, pursuant to CERCLA requirements, to characterize the nature and extent of potential contamination in the soil at potential contaminant source areas identified in studies prior to and during the RI.

JPL is located along the southern edge of the San Gabriel Mountains, at the northern part of the metropolitan Los Angeles area. The JPL site encompasses roughly 176 acres of land situated between the City of La Canada-Flintridge and the unincorporated city of Altadena, of which, approximately 156 acres are federally owned. The remaining property is leased for parking from the City of Pasadena and the Flintridge Riding Club.

Most of the buildings, parking lots, and other developments at JPL are restricted to the southern half of the property. The northern half of the site remains undeveloped because of steeply sloping terrain.

In 1936, Professor Theodore Von Karmen of the California Institute of Technology (CalTech) and a group of students began testing liquid propellant rockets in the Arroyo Seco, a dry stream channel located along the eastern margin of JPL. Several years later, in 1940, the Army Air Corps provided funding for the first permanent structures in the area. The site continued to grow and ultimately became known as the Jet Propulsion Laboratory. In 1958, NASA assumed control of JPL. Today, under a prime contract, CalTech performs research and development tasks at JPL under a prime contract with NASA.

Many of the tasks under JPL's purview require the use of various chemicals and materials, including a variety of solvents, solid and liquid rocket propellants, and cooling-tower chemicals. During the 1940s and 1950s, many buildings at JPL used cesspools to dispose of liquid and solid sanitary wastes collected from the sinks and drains. These cesspools, now called "seepage pits," were designed to allow liquid wastes to seep into the underlying soil. Although abandoned in the 1950s and 1960s, some of the seepage pits may have received volatile organic compounds (VOCs) and other waste materials that are currently found in the either the soil or the groundwater.

In 1980, the presence of three volatile organic compounds, trichloroethene (TCE), tetrachloroethene (PCE), and carbon tetrachloride (CCl_4), was detected in groundwater samples from three City of Pasadena municipal supply wells located near the eastern edge of JPL. Since that time a number of environmentally focused investigations have been conducted at JPL.

During an Expanded Site Inspection at JPL, VOCs were detected at levels above drinking water standards in samples of on-site groundwater. The site was then ranked in accordance with the Federal Hazard Ranking System (HRS) and subsequently placed on the United States Environmental Protection Agency's (EPA) National Priorities List (NPL).

As a result, a comprehensive remedial investigation (RI) of both the on-site soil contaminant source (OU-2) and groundwater (OU-1/OU-3) was initiated. A summary of the previous investigations relevant to the OU-2 RI is provided in the Introduction (Section 1.0) of this report.

The primary objectives of the OU-2 RI include the following:

- To characterize the types of contaminants in the soil at JPL and determine their lateral and vertical extent.
- To determine if identified potential source areas could affect the groundwater beneath JPL.
- To provide sufficient information for the OU-2 feasibility study to identify feasible technologies for potential remediation of the vadose zone at JPL.
- To provide sufficient information on surface soil to a depth of 2 feet to facilitate preparation of human health and ecological risk assessments.
- To provide sufficient information to prepare an assessment of the risks to public health and the environment associated with exposure to on-site soil and soil vapor.

The soils beneath the JPL facility are developed within a relatively thick sequence of alluvial fan type deposits that overlie the crystalline basement complex exposed in the San Gabriel Mountains. The soils that constitute the unsaturated, or vadose zone, beneath JPL are predominantly composed of thick intervals of coarse-grained sand and gravel, with some sporadic intervals of fine-grained sand and silt.

With the primary objectives in mind, the field activities for the OU-2 RI were designed to assess the nature and extent of the constituents of concern in the vadose zone (soil and soil vapor) beneath JPL. Potential source contaminant areas were investigated from 1994 to 1998 during nine sampling events in which either soil or soil-vapor samples were collected from suspected source locations. Soil and soil-vapor samples were collected in an attempt to characterize potential on-site contaminant releases that may have occurred at identified seepage pits/dry wells, waste pits, and discharge points at the JPL facility. A listing of the potential contaminant source areas and the type of sampling conducted at each location is presented in Section 3.0.

The field investigation program for the OU-2 RI was initiated with a shallow soil-vapor survey that was conducted over a 5-day period at 48 locations across the JPL facility and completed on January 18, 1994. This survey was followed by the drilling and sampling of 32 soil borings, including 4 background borings that was started on August 19, 1994, and completed on October 23, 1994; 25 of these borings were converted to nested soil-vapor wells during this time period. From March 11, 1997, through April 14, 1997, an additional three soil borings were drilled, sampled, and converted to soil-vapor wells, and four deep soil-vapor wells were drilled and installed to assess the vertical and lateral extents of the VOC vapors in the vadose zone above the groundwater. Three test pits were also excavated to collect near surface soil samples during this time frame. Eight more deep soil-vapor wells were drilled and installed during the period from March 26, 1998, through April 17, 1998. On June 10, 1999, the test pits previously excavated and sampled on April 14, 1997, were reexcavated and resampled.

Soil-vapor samples were collected during seven sampling events over the course of the OU-2 RI. The preliminary soil vapor probe survey is referred to as Event 1 that was completed on January 18, 1994. Each of the soil vapor well installation programs described above was followed by a pair of soil vapor sampling events (i.e., Events 2 and 3, Events 4 and 5, and Events 6 and 7). Event 2, conducted over a period of 10 days was completed December 29, 1994. Event 3 (4 days) was completed March 10, 1995. Events 4 and 5 (4 days each) were completed on June 26 and July 24, 1997, respectively. Completion dates for Events 6 (11 days) and 7 (5 days) were, respectively, May 29 and June 19, 1998. A complete description of these sampling events is provided in Section 3.0.

Soil samples collected during the OU-2 field program were analyzed for semi-volatile organic compounds (SVOCs), California Title 26 metals plus strontium and hexavalent chromium [Cr(VI)], total petroleum hydrocarbons (TPH), cyanide, dioxins, furans, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), tributyltin, and nitrate (NO_3^-). Samples from the test pits were also analyzed for volatile organic compounds (VOCs). All soil-vapor samples were analyzed for VOCs only.

Results from the soil vapor sampling program (Section 4.0) indicate that VOCs are present in the soil vapor beneath JPL. The data indicate that chlorinated aliphatic compounds and chlorofluorocarbons are the main compounds of potential concern. Four compounds, carbon tetrachloride (CCl_4), trichloroethene (TCE),1,1-2-trichloro-1,2,2-trifluoroethane (Freon 113), and 1,1-dichloroethene (1,1-DCE) were consistently detected at elevated concentrations. Of these, CCl_4 was the most frequently detected compound. The majority of VOC contamination was observed beneath the central and eastern portions of the site, at depths ranging from 20 feet below grade down to groundwater. In most locations where VOCs were detected, VOC concentrations generally increased with increasing depth. Overall, the largest portion of the contamination appears to be related to the seepage pits, waste pits, and disposal areas identified in earlier investigations.

Results from soil samples revealed the presence of a number of analytes that do not occur naturally in soil, including SVOCs, PAHs, PCBs, dioxin, VOCs, cyanide, Cr(VI), tributyltin, and TPH. These compounds were generally detected in areas potentially associated with past waste disposal activities. Furthermore, naturally-occurring compounds or elements detected included NO_3^- and arsenic (As).

Only four SVOCs (excluding PAHs) were detected in JPL soils, including di-n-butylphthalate at a concentration of 250 micrograms per kilogram (μg/kg), butylbenzylphthalate (75 and 160 μg/kg, bis(2-ethylhexyl)phthalate (440 μg/kg), and n-nitroso-di-n-proylamine (500 μg/kg). These compounds were mainly detected in near-surface soil samples from the excavations at test pit Nos. 2 and 2A (TP-2 and TP-2A), although bis(2-ethylhexyl)phthalate was detected in seven soil borings (mostly at depths greater than 30 feet) at concentrations ranging from 86 to 1,900 μg/kg. PAHs were found in the soil borings and test pits that were potentially associated with previous waste disposal activities along the southeast portion of the site. The compounds detected include benzo(b)fluoranthene (8.8 μg/kg), benzo(a)pyrene (4.2 to 5.8 μg/kg), benzo(g,h,i)perylene (11 to 48 μg/kg), fluoranthene (12 μg/kg), indeno(1,2,3-cd)pyrene (67 μg/kg), phenanthrene (12 μg/kg), pyrene (55 to 100 μg/kg), chrysene (18 μg/kg), and benzo(a)anthracene (3.6 to 7.7 μg/kg). The PCBs Arochlor-1254 (200 and 18 μg/kg), and Arochlor-1260 (270 and 21 μg/kg) were only detected in test pit No. 2 (at depths of 1 and 5 feet, respectively), and Arochlor-1232 was detected (33 μg/kg) in test pit No. 1A at a depth of 5 feet. Total petroleum hydrocarbons believed to have originated as lubricating or mineral oils, except for asphalt granules in soil boring No. 1, were detected at concentrations ranging from 2 to 15 milligrams per kilogram (mg/kg) in 13 soil borings. A dioxin congener (1,2,3,4,6,7,8,9-OCDD) was detected two times in soil samples from a depth of 1 foot at concentrations of 9.2 and 5.8 μg/kg in test pit Nos. 2 and 2A, respectively. All of these compounds were evaluated for toxicity and it was determined that they posed negligible to no risk to either human or ecologic receptors.

All elements included in the Title 26 metals suite (plus strontium and hexavalent chromium) were detected in JPL soils with the exception of selenium. Where detected, metal concentrations typically fell within the range of levels measured in the background samples of JPL soils. Arsenic was detected in several locations within the range of concentrations commonly observed in California soils. Hexavalent chromium, which is generally not considered to occur naturally, was also detected in one soil boring (No. 29) and in test pit Nos. 1A, 2A, and 3A. Nitrate, which is believed to have originated from agricultural and landscaping fertilizers, equestrian activities, irrigation waters, and cesspools, was detected in many of the soil borings. Cyanide was detected in samples from only one boring (No. 30), and tributyltin was detected (at the detection limit of 1 μg/kg) in test pit No. 2A. Furans were not detected in any of the soil samples collected at JPL during the OU-2 RI field program.

Migration of VOCs because of volatilization to air is expected to be of little, if any, significance. Although the high vapor pressures favor volatilization, the vertical distribution of VOCs in the soil indicates that overall movement is in the downward direction. This is supported by the

OU-1/OU-3 RI data indicating the presence of VOCs in the groundwater. The groundwater data also suggest that the vertical migration of VOCs is predictable and decreasing in significance. These and other factors related to the environmental fate and transport of COPCs at JPL are discussed in Section 5.0.

Erosion and subsequent eolian transport of potential contaminants residing in surface soil and sediment [primarily SVOCs (including PAHs), PCBs, dioxin, and metals] is expected to be insignificant because concentrations are generally low, and the affected area is very limited. In addition, the vertical migration of metals and organic compounds (other than VOCs) in surface soils and sediments to deeper soil horizons is possible though very unlikely because of the low concentrations at which they were detected, the extremely low aqueous solubility of the analytes and their affinity for the solid phase, and the nature of the soil that impedes their downward movement.

The presence of contaminants in surface and near-surface soil increase the probability of contaminant migration through surface runoff to surrounding on- and off-site receptors, especially during periods of rapid rainfall and flash flooding. However, environmental impacts associated with surface run-off are expected to be insignificant because of the very low concentrations detected in isolated small areas. VOCs released at seepage pits and other source areas at JPL have migrated to groundwater. However, migration of other organic compounds, to the water table, is considered improbable because of the extremely low solubilities and volatilities of the compounds, and their high affinities for the solid phase and adsorption to soil.

The transport of VOCs to groundwater beneath JPL has been demonstrated by the presence of VOCs in soil vapor and the presence of VOCs in groundwater. In addition, Cr(VI) and As have also been detected in JPL groundwater. The presence of the Cr(VI) in groundwater is consistent with Cr(VI) in soil at the site, but occurrences of this element in both the soil and groundwater are infrequent and very localized. Arsenic was also detected in groundwater, but only in a deep, localized portion of the aquifer. This is most likely due to the natural mineralogy of the area.

A baseline human health risk assessment (HHRA) evaluated the potential risks to the child/adult resident, the commercial worker, and the construction worker potentially exposed to contaminants in on-site soil at JPL (Section 6.0). The final list of constituents of potential concern (COPCs) showed that none of the volatile organic chemicals detected in soil-vapor data contributed to risk to potential human receptors. For the soil data, the final COPC list indicates that Arochlor-1254 and Arochlor-1260 at one location; arsenic, at four locations (Waste Pit No. 1/Discharge Point No. 1, Discharge Point No. 3, Discharge Point No. 4, and Waste Pit No. 4); and Cr(VI), at two locations (Waste Pit No.1/Discharge Point No. 1 and Discharge Point No. 2) contribute to carcinogenic and non-carcinogenic risks to potential receptors. However, estimated risks for these COPCs were either below the target hazard quotient (HQ) or within the target risk range established by the EPA. Based on the target levels and the results of the risk calculations, there is negligible risk to potential human receptors, both on-site and off-site, because of exposure to on-site soils at JPL.

A screening-level ecological risk assessment (ERA), using conservative criteria for potential ecological receptors, showed that although some constituents had HQs exceeding 1.0, no risk from exposure to COPCs is expected at JPL.

This screening-level ERA represents a very conservative assessment of potential ecological risks as it incorporates conservative assumptions in each step of the assessment process, including the PRG values and using the maximum soil concentration to represent dietary intake. HQs greater than 1.0 do not automatically imply that adverse toxicological effects exist for biological receptors. Due to this conservatism, and uncertainties inherent in the ERA, HQs between 1.0 and 10 are also considered to pose no additional risk to potential ecological receptors.

Lead is the only constituent that had an HQ greater than 10. These HQs are likely overestimated because of differences in the form of lead used to derive the toxicity values (organic lead) and the likely form of lead present on-site (inorganic lead). In general, organic lead is more toxic than inorganic forms. These HQs may also be overestimated because of the conservatism of the exposure parameters used in the risk assessment. For example, it is assumed that the lead concentration in the dietary intake of the deer mouse is equal to the concentration in soil. In nature, the diet of the deer mouse is largely composed of plants and seeds, which absorb lead from soils only in limited amounts. Animals with large home ranges, such as the American kestrel, are not likely to be at risk since they would potentially obtain only a small fraction of their diet from one location. Additionally, detected lead concentrations are within the range of background values for Californian and western U.S. soils. Thus, potential ecological risks are likely to be lower than indicted by the estimated HQ values.

1.0 INTRODUCTION

Presented in this report are the results of the Remedial Investigation (RI) for Operable Unit 2 (OU-2), Potential On-Site Contaminant Source Areas, at the Jet Propulsion Laboratory (JPL) in Pasadena, California. JPL is a facility owned by the National Aeronautics and Space Administration (NASA) and managed by the California Institute of Technology (CalTech). The term "JPL" is used throughout this document to refer to the facilities located at 4800 Oak Grove Drive in Pasadena, California.

In October 1992, JPL was placed on the National Priorities List (NPL). As a NPL site, JPL is subject to the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, hereafter jointly referred to as CERCLA. Pursuant to CERCLA requirements, this RI was completed at the JPL site to characterize the nature and extent of contamination in soil at potential contaminant source areas identified in studies prior to and during the RI.

The OU-2 RI report is one of two documents to be produced, each associated with operable units at JPL as agreed upon by the United States Environmental Protection Agency, Region IX (EPA), the California State Department of Toxic Substances Control (DTSC), the California Regional Water Quality Control Board, Los Angeles Region (RWQCB), and NASA. The RI for the Groundwater Operable Units, OU-1 and OU-3, pertains to the characterization of on-site and off-site groundwater, respectively. The OU-1 and OU-3 RI report is complete and was final as of August 1999.

Summarized in this RI report are the physical and chemical characteristics of the soil at potential contaminant source areas in OU-2. Also presented in this report are discussions on the nature and extent of contaminants detected in soil, the fate and transport of these contaminants, and the evaluation of human health risks to actual or potential receptors. The information presented in the RI will be used during the Feasibility Study (FS) to identify and evaluate appropriate remedial technologies required specifically for NASA to protect human health and the environment.

1.1 PURPOSE OF REPORT

The primary purpose of the on-site potential contaminant source area investigation is to identify the nature and extent of contaminants in the soils at JPL. To accomplish this, a large amount of soil and soil-vapor data were collected and evaluated. The purpose of the OU-2 RI report is to organize and present these data to meet the following objectives:

- Characterize the types of contaminants and their lateral and vertical extents in the soil at JPL.

- Determine if identified potential source areas could impact on-site groundwater beneath JPL.
- Provide sufficient information for the OU-2 FS to identify feasible technologies for remediation of the vadose zone at JPL.
- Provide sufficient information on surface soil to a depth of 2 feet to facilitate preparations of human health and ecological risk assessments.
- Provide sufficient information to facilitate preparation of an assessment of present and future risks to public health and the environment associated with exposure to on-site soil and soil vapor.

1.2 REPORT ORGANIZATION

The OU-2 RI report consists of eight sections, which are summarized below:

- **Section 1.0: Introduction** – Presentation of background information regarding site location, general physiography, site history and operations. The nature and extent of the on-site vadose zone contamination, as identified through previous investigations, are presented along with a brief description of the study areas, types of investigations, and the results obtained from these previous studies.
- **Section 2.0: Physical Setting** – Description of physiography, topography, surface features, geology, and soils based on site-specific data collected during the RI activities as well as information obtained from previous investigations for the JPL site.
- **Section 3.0: Contaminant Source Investigation** – Descriptions of the OU-2 RI field activities, which include the drilling and sampling of soil borings, the installation and sampling of nested soil-vapor wells, and soil-vapor surveying.
- **Section 4.0: Nature and Extent of Contamination** – Evaluation of the chemical analyses performed on the soil and soil vapor samples collected from the borings, probes, and nested soil-vapor wells. These results are used to assess the nature and extent of vadose zone contamination that are critical in identifying appropriate remediation technologies for the site.
- **Section 5.0: Contaminant Fate and Transport** – Discussion of contaminants occurring in the vadose zone, potential mitigation routes relative to the site conceptual model, and the physical and chemical properties of these contaminants to properly define their transport.
- **Section 6.0: Baseline Risk Assessment** – A human health risk evaluation and a screening-level ecological risk assessment based on the contaminants identified in the vadose zone at the site including exposure assessment, toxicity assessment and risk characterization.
- **Section 7.0: Summary and Conclusions** – A summary of the results of the OU-2 RI activities at JPL and conclusions with recommendations for remedial action objectives.
- **Section 8.0: References** - A complete list of all references used to prepare this report.

1.3 SITE BACKGROUND

This section provides a site description, site history, and a summary of previous investigations associated with the soils at JPL. A review of all previous investigations, including those for groundwater, related to the JPL site is included in the JPL Remedial Investigation Work Plan (Ebasco, 1993a).

1.3.1 Site Description

JPL is located between the city of La Canada-Flintridge and the unincorporated city of Altadena, California, northeast of the 210 Foothill Freeway. A site location map is presented in Figure 1-1. The site is situated on a south facing slope along the base of the southern edge of the east-west trending San Gabriel Mountains at the northern edge of the metropolitan Los Angeles area. The Arroyo Seco, an intermittent streambed, lies immediately to the east and southeast of the site. Within the Arroyo Seco east of JPL is a series of surface impoundments used as surface water collection and spreading basins for groundwater recharge. Residential development, an equestrian club (Flintridge Riding Club), and a Los Angeles County Fire Department Station borders the site along its southwestern and western boundaries. Residential development is also present to the east of JPL, along the eastern edge of the Arroyo Seco.

The JPL site is comprised of approximately 176 acres. Of this, approximately 156 acres are Federally owned, with the remaining land leased from the City of Pasadena and the Flintridge Riding Club for parking. The main developed area of JPL is located on the southern half of the site, which can be divided into two general areas: the northeastern early-developed area and the southwestern later-developed area. The northern half of the site is not developed because of steeply sloping terrain.

Currently, the northeastern early-developed area is used by JPL for project support, testing, and storage facilities, while the southwestern later-developed area houses most of the personnel, administrative, management, laboratory, and project functions of JPL. Further development of JPL is constrained because of steeply sloping terrain to the north, the Arroyo Seco wash to the south and east, and residential development to the west.

Located at the northern boundary of JPL is the Gould Mesa area. This area has widely separated small buildings and is used primarily by JPL for antenna testing. The distance between buildings is a result of the terrain and the need to isolate transmitting and receiving equipment.

The relatively steep mountainside area between Gould Mesa and the well-developed area at JPL is unpopulated. It is accessible to authorized personnel only. The only improvements to this area are water storage tanks and Mesa Road, the road leading to the top of Gould Mesa. Future development in this area is constrained by topography.

Presently, over 150 structures and buildings occupy the JPL site. Total usable building space is approximately 1,330,000 square feet, of which about 40,200 square feet is occupied by trailers and vans. A site facility map is included in Figure 1-2.

Elevation of the JPL site varies from 1,075 feet in the southern portion to 1,550 feet along the northern portion of the site at Gould Mesa. Surface runoff on JPL is generally from north to south. Surface water runoff from the mountains to the north is collected and transmitted by an underground storm-drain system through the developed southern portion of the site and is then discharged into the Arroyo Seco wash. The storm-drain system includes four major drains (24 to 48 inches in diameter) that extend from the northern slopes of the site and terminate at the Arroyo Seco. Branch lines (12 to 24 inches in diameter) collect localized surface drainage and divert the water to the major drains. Runoff from parts of La Canada-Flintridge join the JPL storm drain system at the western edge of JPL, just north of the main JPL entrance (Building 249, Figure 1-2), before being discharged to the Arroyo Seco.

Previous geologic studies conducted on-site have identified an east-west trending and north dipping thrust fault, referred to as the JPL Thrust Fault, crossing the site separating the San Gabriel Mountains to the north from the alluvial slope to the south. At JPL, the alluvial deposits south of the fault range in thickness from 650 to 850 feet and rest on a crystalline basement complex made up of the same general rock types as those comprising the San Gabriel Mountains north of the fault. The unsaturated alluvium at JPL ranges from less than 50 to about 250 feet in thickness and the saturated alluvium ranges between approximately 550 and 600 feet in thickness. The regional groundwater flow across JPL is generally toward the southeast. Occasionally, however, the groundwater flow direction and gradient across JPL can change significantly. Operation of numerous municipal water production wells near the site and the presence of the Arroyo Seco groundwater recharge basins east of the site can occasionally significantly influence the groundwater flow direction and gradient surrounding JPL.

1.3.2 Site History

In 1936, Professor Theodore Von Karmen of the California Institute of Technology (CalTech) and a group of students began testing liquid propellant rockets in the Arroyo Seco. In 1940, the Army Air Corps provided funding for the first permanent structures built near the present-day site. By 1944, the site continued to grow and changed its name to the Jet Propulsion Laboratory, GALCIT. Starting in 1945, the United States began purchasing the parcels of land comprising the JPL site. By the 1950s, with the exception of a small area leased from Pasadena, the United States owned JPL. In 1958, NASA took over control of JPL. Today, under a prime contract, CalTech performs research and development tasks at facilities provided by NASA which are located at the current site of JPL. CalTech also maintains the facilities as part of its contractual agreement with NASA.

Chemicals and materials with a variety of contaminant properties are and have been utilized during the operational history of the site. The general types of materials used and produced include a variety of solvents, solid and liquid rocket propellants, cooling-tower chemicals, and chemical laboratory wastes. During the 1940s and 1950s, many buildings at JPL were constructed with a cesspool to dispose of liquid and solid sanitary wastes collected from drains and sinks within the building. These cesspools were designed to allow liquid wastes to seep into the surrounding soil. The present-day term for these subsurface disposal areas is "seepage pits." Some of the seepage pits may have received volatile organic compounds (VOCs) and other waste materials that are currently found in either the soil or the groundwater. In the late 1950s and early 1960s, a sanitary sewer system was installed and the use of the cesspools for waste disposal was discontinued.

In the 1980s, analyses of groundwater from three City of Pasadena water-supply wells (the Ventura Well, Well 52, and the Arroyo Well) located near JPL indicated concentrations of trichloroethene (TCE), tetrachloroethene (PCE) and carbon tetrachloride (CCl_4) above drinking water standards. Since this time, a number of investigations focusing on environmental issues have been conducted at JPL (see Section 1.3.3 below).

1.3.3 Previous Investigations Related to the Soil and Soil Vapor at JPL

Summaries of studies related to the geotechnical and environmental issues that occurred within OU-2 are included in this section. A more complete synopsis of historical studies, including those for groundwater, performed at JPL is presented in the RI/FS Work Plan (Ebasco, 1993a).

Geotechnical and environmental studies related to the potential on-site contaminant source areas include the following:

- LeRoy Crandall and Associates (1977a), Report of Subsurface Investigation, Overall Investigation of Geology, Soils and Seismic Hazard, Seismic Safety Plan, Jet Propulsion Laboratory Site.
- Agbabian Associates (1977), *Seismic Studies for the Jet Propulsion Laboratory Facilities, Part I, II, and III.*
- LeRoy Crandall and Associates (1977b), *Report of Fault Hazard Study, Jet Propulsion Laboratory.*
- LeRoy Crandall and Associates (1981), *Dewatering Well System, Building 150, Jet Propulsion Laboratory, Pasadena, California.*
- Richard C. Slade (1984), *Preliminary Hydrogeologic Assessment of Soil and Groundwater Monitoring, Jet Propulsion Laboratory, Pasadena, California.*
- Ebasco Services Incorporated (1988a and 1988b), *Preliminary Assessment Report for NASA-Jet Propulsion Laboratory* and *Site Inspection Report for NASA-Jet Propulsion Laboratory.*
- Ebasco Environmental (1990a), *Expanded Site Inspection Report for NASA-Jet Propulsion Laboratory.*

- Ebasco Environmental (1990b), *Supplemental Information to the Expanded Site Inspection Report on the NASA-Jet Propulsion Laboratory.*
- Jet Propulsion Laboratory (1990), Untitled set of memoranda, laboratory analyses, notes, sketches, and other correspondence associated with the removal of storm drain catch basin and associated impacted soil.
- Ebasco Environmental (1991), *(Draft) Remedial Investigation/Feasibility Study Work Plan for NASA-Jet Propulsion Laboratory.*
- Maness Environmental Services, Inc. (1992), *Environmental Site Investigation and Soil Remediation, Jet Propulsion Laboratory, Pasadena, California.*
- Ebasco Environmental (1993b), *Contaminant Source Research (1990 to Present)* in *Work Plan for Performing a Remedial Investigation/Feasibility Study at the NASA–Jet Propulsion Laboratory.*
- Ebasco Environmental (1993c), *Pre-RI Investigation* in *Work Plan for Performing a Remedial Investigation/Feasibility Study at the NASA–Jet Propulsion Laboratory.*
- U.S. Environmental Protection Agency (1993), *Aerial Photographic Analysis of the NASA Jet Propulsion Laboratory, Pasadena, California.*

Brief discussions of these studies are presented in the subsections that follow.

1.3.3.1 LeRoy Crandall and Associates (1977a), *Report of Subsurface Investigation, Overall Investigation of Geology, Soils and Seismic Hazard, Seismic Safety Plan, Jet Propulsion Laboratory*

This investigation was completed to identify the depth to crystalline basement rocks at JPL and to identify specific engineering and dynamic properties of soils at JPL for input into a seismic dynamic analysis to be performed later by Agbabian Associates (see Section 1.3.3.2).

During this study three borings were drilled at locations shown on Figure 1-3. Borings 1 and 3 were drilled to 100 feet below grade to provide information on the properties of the relatively shallow alluvium. Boring 2 was drilled to a depth of 680 feet below grade and encountered crystalline basement rocks at 635 feet below grade. All borings were drilled using mud rotary methods. Boring 2 was subsequently completed to 414 feet with 5-inch-diameter polyvinyl chloride (PVC) blank casing to allow a downhole seismic survey to be performed. Borings 1 and 3 were backfilled and abandoned after drilling.

Analyses performed on the undisturbed soil samples included moisture content, dry density, direct shear (to determine strength at various surcharge pressures), and particle-size distribution. The downhole seismic survey performed in Boring 2 evaluated propagation velocities of compressional and shear waves through the soils surrounding the boring. Data from this report that is useful for the current OU-2 RI include the descriptions and physical properties of the alluvium in Borings 1 and 3.

1.3.3.2 Agbabian Associates (1977), *Seismic Studies for the Jet Propulsion Laboratory Facilities, Parts I, II, and III*

Agbabian Associates completed a three-part seismic study of JPL in 1977. As part of the study, previous geologic and seismologic investigations were summarized, the location of the JPL Thrust Fault was reevaluated and mapped, data from a trench cut across the JPL Thrust Fault at the mouth of the Arroyo Seco by a CalTech research team were examined, and existing seismic data on the subsurface conditions at JPL were reevaluated. A cross section of the trench cut across the JPL Thrust Fault by the CalTech research team is included as Figure 1-4. This trench was 40 feet long and 5 to 8 feet deep, excavated with a backhoe, and located just north of the JPL bridge (see Figure 1-5). In this trench, granitic rocks were found overlying alluvium along a fault contact that dipped to the northeast at an angle between 30 to 40 degrees from horizontal.

As part of the Agbabian Associates' study, the trace of the JPL Thrust Fault across the JPL facility was mapped. Agbabian Associates' interpretations of the trace of the JPL Thrust Fault are included in Figure 1-5.

Conclusions of Part I of Agbabian Associates' study related to the geology of the site include the following:

- The JPL Thrust Fault is part of the Sierra Madre Fault system.
- No evidence was found for, or against, displacement along the JPL Thrust Fault within the past 10,000 to 12,000 years.
- Additional work is required to further evaluate the activity or inactivity of the JPL Thrust Fault and better define its trace in the western half of JPL. Agbabian Associates recommended additional trenching across the fault to address these issues.

Part II of the study, "Supplemental Geologic Studies for the Jet Propulsion Laboratory Facilities," reported the results of additional investigations recommended in Part I. Included in the additional investigations was further trenching across the JPL Thrust Fault in hopes of finding evidence for dating fault activity. LeRoy Crandall and Associates excavated a trench across the JPL Thrust Fault west of the trench excavated by CalTech (Figure 1-5). The trench was 36 feet long and had a maximum depth of 12 feet. The JPL Thrust Fault, as exposed along the length of the trench (Figure 1-6), strikes east-west and has an apparent dip to the north of approximately 24 degrees. Because of surface restrictions, the trench was cut oblique (N 50° E) to the east-west trace of the fault. A sample of calcium carbonate precipitate, which was interpreted to have been deposited after the last fault movement, was collected from the trench and isotopically dated using carbon-14 technology. It was concluded that the calcium carbonate was formed between 800 and 2,000 years ago.

Part III of Agbabian Associates' study, "Implications of Fault Hazard for the Jet Propulsion Laboratory Master Plan," discussed recommendations for the use of existing facilities and for land development within zones of potential earthquake induced surface rupture on the JPL property. These recommendations were based on information obtained during the Part I and Part II studies.

The Agbabian studies were originally intended for earthquake and seismic evaluations only and were not conducted to collect CERCLA RI related information. However, results of Agbabian Associates' work provide insight into the location of the JPL Thrust Fault. This information was used to help the CERCLA effort in understanding the geologic structure of the site and its potential impact on groundwater flow and contaminant transport.

1.3.3.3 LeRoy Crandall and Associates (1977b), *Report of Fault Hazard Study, Jet Propulsion Laboratory*

This investigation was completed, primarily, to further locate the JPL Thrust Fault along the western portion of JPL so that buildings within the potential rupture zone of the fault could be better identified. In addition, the report discussed potential seismic hazards for a proposed water reservoir and included recommendations for minimizing the rupturing of critical pipelines during fault movement. During this investigation, 11 soil borings were drilled to depths ranging between 33 and 800 feet. The locations and total depths drilled for these borings are shown on Figure 1-7. Listed below is a summary of important geologic data concerning the borings:

Boring No.	Total Depth in Feet	Remarks
1	100	Entirely in alluvium (drilled during Crandall, 1977a, investigation)
2	680	Granitic rock at 635 ft (drilled during Crandall, 1977a, investigation)
3	100	Entirely in alluvium (drilled during Crandall, 1977a, investigation)
4	800	Entirely in alluvium
5	169.5	Encountered fault at 157 ft
6	135	Encountered fault at 122 ft
7	272	Bottom in granitic rock
8	210	Entirely in alluvium
9	259	Encountered fault at 248 ft
10	110	Bottom in granitic rock
11	323	Entirely in alluvium
12	33	Bottom in granitic rock
13	243	Entirely in alluvium
14	243.5	Encountered fault at 230 ft

All borings were drilled with mud rotary drilling methods and all soil types were logged during drilling. Soil samples and cores of crystalline basement rock were collected for further evaluation, if necessary. The boring logs were given to a CalTech research team who interpreted the trace of the JPL Thrust Fault and estimated the potential associated rupture zone. The trace of the fault, as developed from the boring logs, is shown on Figure 1-7. The fault plane was penetrated four times during this study and several borings were strategically located to place limits on the possible location of the fault plane.

1.3.3.4 LeRoy Crandall and Associates (1981), *Dewatering Well System, Building 150, Jet Propulsion Laboratory, Pasadena, California*

In 1981, LeRoy Crandall and Associates installed a soil dewatering system along the north side of Building 150 at JPL. During periods of high precipitation, surface water runoff water entered the basement of Building 150.

The dewatering system consisted of one 12-inch-diameter, 60-foot-deep pumping well, and two 4-inch-diameter, 40-foot-deep observation wells installed at distances of 40 feet and 80 feet, respectively, away from the pumping well. During drilling of the 60-foot pumping well, crystalline basement rock was encountered at a depth of approximately 2 feet below grade. Crystalline basement rock was encountered in Observation Well No. 1 at approximately 15 feet below grade and in Observation Well No. 2 at approximately 20.5 feet below grade. Overlying the basement rocks, alluvial soils, consisting of silty sand and sand with gravel and cobbles, were encountered.

This study was conducted for purposes other than CERCLA. However, the shallow nature of the crystalline basement rocks north of the main trace of the JPL Thrust Fault provides further insight on the geologic nature of the site.

1.3.3.5 Richard C. Slade (1984), *Preliminary Hydrogeologic Assessment of Soil and Groundwater Monitoring, Jet Propulsion Laboratory, Pasadena, California*

Richard C. Slade completed a preliminary assessment of soils and groundwater at JPL in 1984. The purpose of this work was to provide a hydrogeologic assessment based on results of laboratory data generated from soil and groundwater samples collected on and near JPL.

This investigation included the excavation of trenches at two abandoned cesspools (seepage pits) at JPL and the collection of groundwater samples from the City of Pasadena monitoring well MH-01. The seepage pits were located southwest of former Building 59 (Seepage Pit No. 16) and southwest of former Building 65 (Seepage Pit No. 13). Both buildings previously housed chemistry laboratories.

Exploration of these two former seepage pits included the excavation of three to four trenches at each site and the collection of soil samples for laboratory analysis. The trenches ranged in depth from 8 to 13 feet and were excavated using a backhoe equipped with a 2-foot-wide bucket. None of the trenches were excavated to the bottom of the seepage pits. Soil samples were collected at depths ranging from 1 to 9.5 feet. Relatively undisturbed samples were obtained from the in-place materials exposed in the trench walls by driving a brass sampling sleeve into the soil and immediately capping both ends of the sleeve. Soil samples were analyzed specifically for CCl_4, TCE, PCE, and 1,1,1-trichloroethane (TCA) by liquid extraction testing methods, for metals by qualitative and semi-quantitative emission spectroscopy methods, for fluoride and chromium (methods not reported), and pH.

Laboratory analyses of the relatively undisturbed soil samples did not detect any VOCs. However, lead was detected at a concentration of about 200 milligrams per kilogram (mg/kg) in the sample collected at a depth of 7 feet from the seepage pit adjacent to former Building 59. The source of this lead was not determined. Test results for all other elements were considered to be within the range of values for the respective element based on its natural abundance in the earth's crust. Analytical results for all laboratory tests, except VOCs, are presented in Table 1-1.

Although the Richard C. Slade investigation was not performed pursuant to the CERCLA investigation and the testing methods utilized are not normally used in contaminant evaluations, the results do provide information on two of the potential contaminant source locations.

1.3.3.6 Ebasco Services Incorporated (1988a and 1988b), *Preliminary Assessment Report for NASA-Jet Propulsion Laboratory and Site Inspection Report for NASA-Jet Propulsion Laboratory*

A Preliminary Assessment (PA) and a Site Inspection (SI), as mandated by CERCLA, was performed at JPL by Ebasco in 1988. During the PA, potential areas of concern were identified that included abandoned solid waste disposal pits, seepage pits (cesspools), past chemical spills, and VOC contamination in three City of Pasadena municipal water supply wells located downgradient from the JPL site. These concerns were evaluated through interviews, a literature review, and a reconnaissance of the alleged waste-disposal and chemical-spill areas during the SI activities. The purpose of the PA and SI was to obtain the necessary information for computing a preliminary Hazard Ranking System (HRS) score. Neither subsurface explorations nor analytical work was conducted during the PA and SI activities.

Six pits or old waste disposal sites on and adjacent to JPL property (Figure 1-8) were discussed in the PA and SI reports. Based on information available at the time the PA and SI reports were prepared, it was reported that the pits ranged from 5 to 30 feet wide and 15 to 30 feet deep, and were used between 1945 and 1960 for disposal of municipal wastes, and solid and liquid hazardous wastes. Erroneously, all six pits were denoted as seepage pits in the PA and SI reports when, in fact, only two were actual seepage pits (cesspools). These two pits were investigated by Richard C. Slade in 1984 (discussed previously in Section 1.3.3.5), and only a lead concentration of about 200 ppm was found in the soil near one of these pits (Pit 4) at that time.

Below is a summary of each of the pits, or waste disposal sites, as discussed in the PA and SI reports, although information obtained subsequently disputes some of these earlier conclusions.

- Seepage Pit 1 (Waste disposal area now designated as WP-1): Believed to be located near Building 103 outside of the JPL property line in the Arroyo Seco dry wash and is not associated with any JPL building. This area was approximately 15 feet in diameter, of unknown depth, and was used primarily for disposal of municipal solid wastes. However, according to available information, chemical wastes were also disposed here including solvents, Freon, mercury, liquid and solid rocket propellants, cooling tower chemicals, and sulfuric acid. Other information indicated that the pit was not used for disposing liquid wastes.

- Seepage Pit 2 (Solid waste disposal area now designated as WP-2): Believed to be located in the parking lot south of Buildings 300 and 302. This pit was approximately 30 feet wide and 15 feet deep. Wastes disposed at this pit were reported to be similar to those disposed of at Pit 1. The site was also used for burning debris and for disposal of fluorescent lights and scrap magnesium.
- Seepage Pit 3 (Now designated as Seepage Pit No. 28): Located north of former Building 77 and beneath the existing Building 299. The pit was approximately 5 feet in diameter and about 30 feet deep, and was reportedly used primarily for the disposal of propellants and mixed solvents. (This pit was initially designed to receive exhaust gases from an experimental propulsion system that used fluorine gas as a propellant).
- Seepage Pit 4 (Now designated as Seepage Pit No. 16): Located near Building 303 and previously used for disposal of liquid wastes from former Building 59. This pit was apparently used for the disposal of chemistry lab wastes. This pit location was investigated down to a depth of 11 feet in 1984 by Richard C. Slade (Slade, 1984). Lead in a concentration of about 200 ppm was found in the soil at a depth of 7 feet. No other contaminants were found.
- Seepage Pit 5 (Now designated as Seepage Pit No. 13): Located near Building 302 and previously used for disposal of liquid wastes from former Building 65. This pit was also apparently used for the disposal of chemistry lab wastes. Richard C. Slade also investigated this pit in 1984 (Slade, 1984) and did not find any contaminants in the soil down to a depth of 9.5 feet.
- Seepage Pit 6 (Background soil-sample location): Located near Building 97 on a previous natural slope. This location was initially believed to be near a former chemistry lab that used this area for disposal of lab wastes. (This area was selected by Richard C. Slade for obtaining uncontaminated soil samples so that chemical analyses results could be compared with those associated with Buildings 59 and 65.) Slade investigated this area down to 11 feet and no contaminants above background levels were detected (Slade, 1984).

The information obtained and reviewed during the PA and SI was used to calculate an unofficial HRS score for JPL. Therefore, the PA and SI were the first "official" documents prepared for the CERCLA process. The resulting preliminary HRS score was 38.3, using the unrevised EPA method of calculation. This was above the 28.5 criteria required in the past for a site to be considered for inclusion on the National Priorities List (NPL).

These reports were required by CERCLA. The study was a review of potential sources only. No analytical work (lab work) was completed. Along with a preliminary HRS score, these reports provided valuable information in the form of insight into the source types and locations. This information served as the basis of extensive additional source research.

1.3.3.7 Ebasco Environmental (1990a), *Expanded Site Inspection Report for Jet Propulsion Laboratory*

Between January and March 1990, field activities for an Expanded Site Inspection (ESI) were conducted at JPL by Ebasco Environmental (currently known as Foster Wheeler Environmental Corporation). The objectives of the ESI were to obtain additional information on potential contaminants in the groundwater and soils at JPL by installing five groundwater monitoring wells and conducting limited soil vapor surveys at suspected waste disposal sites identified during previous investigations. During the ESI, the five groundwater monitoring wells were installed and 38 passive soil-vapor collectors were used to obtain preliminary data on the extent of contaminants in the soil at the locations shown in Figure 1-9. These data were collected to support the EPA's calculation of the final HRS score for JPL in order to determine whether or not JPL should be included on the National Priorities List (NPL).

Soil vapors at JPL were sampled using passive soil-vapor collectors consisting of a ferro-magnetic wire coated with activated charcoal contained in a glass culture tube. The culture tubes were buried open-end downward in 1-foot-deep holes drilled with a 3-inch-diameter hand auger, and the collectors were left undisturbed for approximately 4 weeks. A schematic diagram of a soil-vapor collector buried in the ground is presented in Figure 1-10.

During the 4 weeks the collectors were left buried, volatile organic vapors present in the soil beneath the collectors could adsorb onto the activated charcoal. The collectors were then removed, sealed immediately, and transported to the manufacturer's analytical laboratory (Petrex) where the adsorbed compounds were desorbed and analyzed using Curie-point mass spectrometry. The results were then compared to a library of mass spectra of known compounds and identified. Results are reported in terms of ion counts at various mass-to-charge ratios and provide a semi-quantitative measure of concentrations.

Results from the soil-vapor analyses were evaluated by using an order-of-magnitude ranking system in which net or background-corrected ion counts are ranked as not detected (zero ion counts), very low (1 to 4,999), low (5,000 to 9,999), moderate (10,000 to 49,999), or high (50,000 or greater). Duplicate wire collectors are averaged before ranking.

Six different volatile organic compounds (VOCs) were detected in one or more samples during the soil-vapor survey and are listed below.

- Benzene, toluene, and xylene (BTX)
- Trichloroethane (TCA)
- Trichlorofluoromethane (Freon 11) or Trichlorotrifluoroethane (Freon 113)
- Trichloroethene (TCE)
- Tetrachloroethene (PCE)
- Chloroform

Relative concentrations of these VOCs are presented in terms of net ion counts for each soil-vapor collector wire in Table 1-2, and major VOC detections are also shown in Figure 1-9. Equations relating ion counts with the true concentrations and flux of analytes in soil-vapor are not available.

The importance of the ESI work to the CERCLA effort was that it provided the first evaluation of on-site groundwater conditions, and it identified the presence of VOCs in the on-site soils that were similar to those found in the groundwater beneath JPL and in the City of Pasadena wells. Information generated during the ESI provided significant input to the CERCLA effort and to the development of the RI/FS Work Plan and the OU-2 FSAP.

1.3.3.8 Ebasco Environmental (1990b), *Supplemental Information to the Expanded Site Inspection Report on the NASA-Jet Propulsion Laboratory*

After the ESI was completed, the HRS scoring method was revised by the EPA. The revisions increased the amount and detail of data required by the EPA to evaluate potential threats to public health and the environment while scoring a site for potential inclusion on the NPL. A report, that included additional information not previously provided to the EPA, was prepared and submitted so that the EPA could complete their HRS scoring for JPL with the newly revised system. Discussions and data relating to waste characteristics, the groundwater migration pathway, the surface water migration pathway, the air migration pathway, and the on-site soil exposure pathway were included in this report (Ebasco, 1990b). Brief summaries of topics relative to OU-2 (waste characteristics, surface water migration pathway, and on-site soil pathway) are presented below.

Waste Characteristics

After the completion of the ESI, additional information about past waste-disposal activities and procedures were newly identified to further clarify the characteristics of wastes present at JPL. This information revealed that, of the original six waste pits identified previously in the PA and SI, only two of the pits were apparently constructed for the purpose of disposing wastes other than sanitary wastes. One of these pits (Pit 2, now designated as WP-2) was reportedly used for the disposal of glass and metal shavings. The other pit (Pit 3, now designated as Seepage Pit No. 28) was suspected to have been used as a fluorine scrubber. This pit was originally designed to receive exhaust gases and neutralize any fluoric acid produced during experimental testing of a propulsion device that used fluorine gas as a propellant component. Two other pits (Pits 1 and 6) were apparently not actual "pits", but were open areas where various liquid wastes may have been disposed. Pit 1 could have been an erosional feature at the south end of Building 103, and this area is now designated as WP-1. Pit 6 is the location where Richard C. Slade obtained background soil samples for comparative purposes (see Section 1.3.3.5) during his investigations near former Buildings 59 and 65. The last two pits identified (Pits 4 and 5) were apparently cesspools (now designated as Seepage Pit Nos. 16 and 13, respectively) used for disposal of liquid and solid wastes. The cesspools were designed to allow liquid wastes to seep into the surrounding soil, and have apparently been referred to as seepage pits in the past. Information gathered during interviews with employees indicated that many of the buildings present at JPL before the current sewer systems were installed (circa 1960) had cesspools. The cesspools may have received various quantities of chemical wastes since most of the buildings at JPL either stored or used various chemicals. These cesspools are, or were, important potential sources of soil and groundwater contaminants at JPL.

Surface Water Migration Pathway

Descriptions were provided on the physical characteristics of the ground surface at JPL, JPL's storm-drainage system, the physical characteristics and uses of the Arroyo Seco, stream-gauge data from the Arroyo Seco, watershed boundaries near JPL and the City of Pasadena's plans at that time for the Arroyo Seco.

Surface runoff at JPL is generally from north to south. Surface water from the mountains to the north of JPL is collected and transmitted across the developed portion of the site by an underground storm-drain system and then discharged into the Arroyo Seco. The storm-drain system, designed to control runoff from a calculated maximum rainstorm within a 50-year period, includes four major drains (24 to 48 inches in diameter) that extend from the northern slopes of JPL and terminate at the Arroyo. Branch lines (12 to 24 inches in diameter) collect localized surface drainage and divert the water to the major drains (Boyle Engineering, 1988). A layout of the existing storm drain system is presented in Figure 1-11. JPL records and personnel accounts indicate no problems with local flooding with the exception of unfinished construction sites.

Surface sediment samples were collected from the stream channel in the Arroyo Seco at the locations shown in Figure 1-12. After 2 to 3 inches of sediment were removed from the surface, sediment samples were collected by driving a 2-inch-diameter by 6-inch-long stainless steel sample tube into the soil with a hand held, sliding hammer-drive soil sampler. The sediment samples were analyzed for VOCs (EPA Method 8240), semi-volatile organic compounds (SVOCs) (EPA Method 8270), California Code of Regulations Title 22 metals plus strontium (EPA Methods 6010/7000 series), organochlorine pesticides and PCBs (EPA Method 8080), TPH (EPA Method 418.1), and cyanide (EPA Method 335.2). The analytical results of these analyses are summarized in Table 1-3. No VOCs, SVOCs, organochlorine pesticides, or PCBs were detected in any near-surface sediment sample. However, some metals, cyanide, and TPH were detected in low concentrations.

On-Site Soil Exposure Pathway

Target populations of employees working at JPL and residents within 1 mile of JPL were presented along with a discussion on access restriction to the site. The resident population within 1 mile of JPL was estimated to be 6,914. In addition, employees numbered approximately 8,000 in 1990.

Since two of the former waste pits identified in the PA and SI (Pits 1 and 2, which are now designated as WP-1 and WP-2, respectively) may have been located wholly or partially outside the current JPL property limits, soil borings were drilled and soil samples were collected to assess the possibility of human exposure to substances that may have been deposited in these pits. Four soil borings were hand augered to depths of 2 feet at the locations shown in Figure 1-13 and five soil samples (including a background sample and a QA/QC duplicate sample) were collected from a depth interval of 1.5 to 2 feet.

The soil samples were analyzed for VOCs (EPA Method 8240), SVOCs (EPA Method 8270), California Code of Regulations Title 22 metals plus strontium (EPA Methods 6010/7000 series), organochlorine pesticides and PCBs (EPA Method 8080), TPH (EPA Method 418.1), and cyanide (EPA Method 335.2).

No volatile organics, semi-volatile organics, organochlorine pesticides, PCBs, or cyanide were detected in any soil sample. Some metals and TPH, detected in low concentrations, are summarized in Table 1-4.

In summary, the supplemental information provided to the EPA was important to the OU-2 CERCLA effort in that the information provided additional insight as to the nature of the potential contaminant-source areas, and it provided the basis from which an exhaustive contaminant research effort (Section 1.3.3.12) was initiated.

1.3.3.9 Jet Propulsion Laboratory (1990), Untitled set of memoranda, laboratory analyses, notes, sketches, and other correspondence associated with the removal of a storm drain catch basin and associated impacted soil

In November 1990, during a JPL facilities construction project that involved the demolition of six buildings near the east gate (former Buildings 20, 23, 31, 32, 81 and 134) and realignment of Explorer Road, a construction crew demolished a relatively large catch basin that was part of the site-wide storm-drain system installed over 30 years ago. This portion of the site is historically the oldest part of JPL and may have been an area subjected to long-term chemical and solvent usage.

The catch basin was located approximately 20 to 25 feet from the front of the east end of Building 107 and was constructed of reinforced concrete. Dimensions of the catch basin were reported to be approximately 6 feet by 6 feet by 10 feet deep. The top of the catch basin was level with the surrounding surface grade and contained an open steel grating that allowed storm-water runoff and associated debris to flow into the basin. Additional runoff flowed into the chamber from an inlet pipe connected to two smaller catch basins located upstream. Solid materials entering the chamber were allowed to settle before water flowed out a discharge line that emptied to the Arroyo.

When the catch basin was demolished on November 30, 1990, it contained approximately 4 feet of saturated, very dark-gray silt and sand with about 2 feet of liquid on top. After the catch basin had been broken up, the basin's contents were reportedly going to be used as backfill material in the excavation and had been mixed with the surrounding soils. However, after mixing, the soils were recognized as being contaminated, and soil samples were collected and sent by JPL personnel to a laboratory for analysis on a "rush" basis. The samples were analyzed for total metals by EPA Methods 6010/7000 series, cyanide by EPA Method 8010, TPH by EPA Method 8015 (modified for gasoline), pesticides and PCBs by EPA Method 8080, VOCs by EPA Method 8240, and SVOCs by EPA Method 8270.

Results of these analyses indicated that the soil materials in the catch basin contained CCl_4 at an estimated concentration of 13,400 mg/kg along with lesser amounts of other solvents. A summary of VOCs and other chemical compounds detected is presented in Table 1-5.

Approximately 60 cubic yards of material were subsequently excavated on December 15, 1990 for off-site disposal. When the excavation reached a depth of approximately 12 feet, part of an unmortared brick-lined seepage pit (see Seepage Pit No. 36, Table 1-6) was encountered. This pit was located directly beneath the concrete catch basin.

Three additional samples were then collected from areas that visually appeared to be the most contaminated (darkest discoloration). Based on the analysis of these samples, another 100 cubic yards of soil (including some concrete) were excavated on December 18, 1990 for off-site disposal. All excavated materials (total of 160 cubic yards) were placed in roll-off bins and stored at the south end of JPL's east parking lot until they were transported to a Class I landfill at Grassy Mountain, Utah. Available records indicate that additional soil samples were not analyzed after the 160 cubic yards of soil were removed from the site. The catch-basin excavation was backfilled with lean-concrete.

The catch basin was uncovered as a part of routine JPL facilities modification. While the work was not completed as part of the CERCLA process, it did provide insight that the source identification efforts were properly focused since the contamination could only occur by hand-dumping solvents and chemicals into the storm-drain openings.

1.3.3.10 Ebasco Environmental (1991), *(Draft) Remedial Investigation/Feasibility Study Work Plan for NASA-Jet Propulsion Laboratory*

In January 1991, a pre-RI draft work plan for additional contaminant-source exploration and groundwater characterization was prepared based on all information available at that time. The planned scope of work included the drilling and sampling of soil borings at suspected contaminant-source locations and the installation of monitoring wells to further evaluate the lateral and vertical extents of on-site and off-site volatile organic compounds (VOCs). Following the completion of the field work, all of the analytical data collected, with the incorporation of existing data, would be evaluated as part of a risk assessment (RA) to potential receptors.

The purpose of that effort would be to quantify risks posed by the VOCs in groundwater and source areas and set forth criteria that could be used to evaluate remedial alternatives.

It was planned that at least 22 borings would be drilled and sampled to an approximate depth of 60 feet at selected seepage pit locations accessible to drilling equipment and at other locations where there was high probability that solvents and chemicals had been dumped or allowed to seep into the subsurface soils. Based on the chemical analysis of samples from these borings, other seepage pit locations in close proximity to those explored would also be drilled and sampled. In addition, if it could be determined that other seepage pit locations were accessible to drilling equipment, they would also be drilled and sampled.

Two seepage pits (Nos. 22 and 27) were eliminated from the pre-RI exploration program because there was no evidence of solvent or chemical usage associated with their history, and 11 other seepage pit locations (Nos. 4, 7, 8, 9, 10, 11, 13, 13A, 25, 28, and 32) were deemed to be inaccessible to drilling equipment because of terrain or by being located under existing structures. A listing of the 40 seepage pits and dry wells identified at the time the draft work plan was prepared is presented in Table 1-6 and their locations are shown in Figure 1-14.

Installation of four monitoring wells was also planned. Three of these wells would be shallow standpipe wells having a screened interval of 50 feet at the bottom of each well. The fourth well, a multiple-screened well having at least five 10-foot sections of screen at various depths within the aquifer, would be on the order of 650 to 700 feet in total depth. The purposes for these wells are to obtain water-quality samples downgradient from suspected contaminant sources and to help assess the vertical extent of volatile organic compounds in the groundwater.

In summary, this work plan was submitted to EPA prior to listing on the NPL. It was believed much of the work would be valuable regardless of when the work was completed. As a result, a limited soil-vapor study, a limited soil-boring study, and the groundwater well installations were completed. The limited studies pertaining to OU-2 are discussed in Section 1.3.3.13.

1.3.3.11 Maness Environmental Services, Inc. (1992), *Environmental Site Investigation and Soil Remediation, Jet Propulsion Laboratory, Pasadena, California*

In August 1991, during the excavation for the Optical Instruments Laboratory's (Building 306) foundations and bottom floor, the construction contractor, Kitchell Contractors, Inc., encountered a layer of soil that appeared to be contaminated with petroleum hydrocarbons. Maness Environmental Services, Inc. (Maness) was retained to evaluate the extent of the contaminated soil and determine the most cost- and time-effective method for remediating the site.

It was initially estimated that the amount of contaminated soil encountered ranged between 50 to 100 cubic yards (cu yd). However, after Maness began their excavation in the impacted area, it became apparent that there was more contaminated soil than originally estimated. Fourteen soil samples were collected from Maness's excavation in the most visually stained areas and analyzed for total recoverable petroleum hydrocarbons (TRPH) by EPA Method 418.1. TRPH concentrations in these samples ranged from a low of 38 milligrams per kilogram (mg/kg) to a high of 3,000 mg/kg and averaged about 700 mg/kg. Since the source of contamination was unknown, and other materials (e.g., shrubs, trees and tree stumps, railroad ties, piping, broken concrete, etc.) had been removed from a gully occupying part of the site, five samples were composited in the laboratory and analyzed for TRPH by EPA Method 418.1, volatile organic compounds (VOCs) by EPA Method 8240, semi-volatile organic compounds (SVOCs) by EPA Method 8270, pesticides and PCBs by EPA Method 8080A, California Code of Regulations Title 22 metals by EPA Methods 6010/7000 series, cyanide by EPA Method 335.2, and toxicity characteristic leachate potential (TCLP) for purgeable organics (8240) and semi-volatiles (8270). In addition, a bioassay toxicity test was conducted on the composite sample to determine whether the contaminated soil is hazardous in accordance with Title 22 of the California Code of Regulations. Results of these analyses performed on the composite sample are summarized in Table 1-7.

Based on the results of these analyses, the contaminated soil at the construction site was determined to be non-hazardous in accordance with Title 22 criteria. Most of the contamination appeared to be comprised of heavy-end petroleum hydrocarbons from unknown sources. Based on the other types of debris found in the contaminated soil, the gully is believed to have served as a local dumping area prior to NASA acquiring the property.

Since these initial explorations indicated that the contamination was deeper than anticipated, a limited soil-boring program (six hollow stem auger borings) was conducted to evaluate the vertical and lateral extent of the contamination east of the west soldier-pile wall. Soil samples were collected with a split-spoon sampler using brass sleeves at depths of 3, 5, 10, 15, and 20 feet, and they were analyzed for TRPH by a mobile laboratory on the site. If the samples contained TRPH concentrations of 50 mg/kg or greater, the samples were also analyzed for aromatic volatiles (benzene, toluene, ethylbenzene, and total xylenes) by EPA Method 8020 and California Department of Health Services Method 8015 modified for diesel fuel.

Elevated concentrations of TRPH ranging from 21 to 5,500 mg/kg at an average depth of about 5 feet were found in the six borings. The sample that contained 5,500 mg/kg TRPH also contained 94 mg/kg of diesel; aromatic volatiles were not detected in any of the samples collected from these borings. Because of the unexpected levels of contamination encountered in the 6 borings, an additional 24 soil borings were drilled and sampled in a grid pattern over the construction site within the footprint of Building 306 (Figure 1-15). The same sampling and analysis rationale was followed for the additional borings with the exception that the next sampling depth in a boring would not be sampled if the sample above the depth contained less than 50 mg/kg TRPH.

Based on the results of this sampling and analysis program, it was determined that soil contaminated with petroleum hydrocarbons existed to an average depth of 5 feet throughout the entire building construction site on the east side of the west soldier-pile wall. Soil samples were not collected from the west side of the wall. Eighty-four samples were analyzed for TRPH and 33 were analyzed for diesel and BTEX. Results of these analyses are presented in Table 1-8.

Similar to the soil boring and sampling program, the stockpiles of soil materials excavated during initial construction were investigated using hand-auger and hammer-drive techniques to obtain discrete samples. These samples were analyzed for TRPH, diesel and BTEX using the same rationale as for the samples collected during the soil boring program. Results of these analyses also indicated elevated levels of heavy-end petroleum hydrocarbons with traces of diesel fuel and no detectable concentrations of gasoline.

Following the general profiling of the contaminated soils that still needed to be excavated and those contained in the stockpiles, more than 150 screening samples were analyzed during their removal and transportation to a suitable Class II or Class III landfill. The Los Angeles Regional Water Quality Control Board requirements stipulate that the maximum acceptable levels for discharge into a Class III landfill for soils impacted with waste oil, crude oil, or diesel fuel is 1,000 mg/kg TRPH. For soils impacted with gasoline, the maximum acceptance level is 100 mg/kg TRPH, 0.07 mg/kg benzene, 10.0 mg/kg toluene, 68.0 mg/kg ethylbenzene, and 62.0 mg/kg total xylenes. Soils contaminated with concentrations exceeding these levels are required to be discharged into a Class II landfill.

Excavation and removal of the contaminated soils started November 5, 1991, and continued through mid-January 1992. Approximately 16,130 tons of non-hazardous contaminated soil was transported to and disposed as Class III material at Laidlaw's Waste Systems Chiquita Canyon Facility in Valencia, California, and approximately 2,870 tons were transported to and disposed as Class II material at Laidlaw's Lokern Facility in Buttonwillow, California.

Confirmation sampling and analysis were continued at the locations shown in Figure 1-16, with some additional excavation being required, within the building's foundation area until TRPH concentrations were reported as non-detectable. It was decided that soil with minimal levels of TRPH (50 mg/kg or less) would be left in place and capped by the proposed parking lot's asphalt.

1.3.3.12 Ebasco Environmental (1993b), *Contaminant Source Research (1990 to Present)* in *Work Plan for Performing a Remedial Investigation/Feasibility Study at the NASA-Jet Propulsion Laboratory*

Following the compilation of new information concerning contaminant-source identification and locations that was obtained during the revisions to the HRS score (Ebasco, 1990b), efforts were continued to search records, aerial photographs, drawings in the files, and to interview employees. These research efforts continued through the completion of the RI.

Information from Interviews

In 1988, six disposal sites on JPL were identified as "seepage pits" and discussed in the PA and SI reports (Ebasco, 1988a and 1988b, respectively) and are shown in Figure 1-8 (see Section 1.3.3.6). After the ESI (Ebasco, 1990a) was completed, additional information was obtained from current and retired employees about past waste-disposal activities and procedures that assisted in clarifying the waste characteristics. The personnel interviewed are listed on the next page.

PERSONNEL INTERVIEWED AT JPL

Name	Title or Affiliation
Roscoe Edwards (Retired)	Facilities Maintenance and Operation Section
Rich MacGillivray	Facilities Maintenance and Operation Section
Rudy Russ	Facilities Maintenance and Operation Section
Steve Stefanovich	Facilities Maintenance and Operation Section
Lane Prior (Retired)	Safety Officer
Don Boyer	Propulsion Section Administrator
Willis Thurston (Retired)	Test Pit Technician, Section Safety Coordinator
Bill Fehlings	Facilities Maintenance and Operation Section
Warren Dowler	Propulsion and Chemical Systems Section
Bill Beale	Observational Systems Section
Dick Mucciolo	Observational Systems Section
Ed Jones	Guidance and Control Section

It was learned that of the six waste pits previously identified in the PA and SI, only Pits 2 and 3 on Figure 1-8 were apparently constructed for the purpose of disposing wastes other than sanitary wastes. Pit 2 (now designated as WP-2, Figure 1-14) in this figure is shown on the aerial photograph in Figure 1-17. This unlined pit, bulldozed in the Arroyo Seco, was reportedly used for the disposal of glass and metal shavings. Pit 2 can be seen in aerial photographs taken from 1947 to 1953, but is not present in an aerial photograph taken in 1959. Pit 3 (now designated as Seepage Pit No. 28), on Figure 1-8, is shown on the aerial photograph in Figure 1-18. Pit 3 was identified as part of a test cell where a propulsion system that used fluorine gas was being developed.

To clarify the pit numbers used in previous documents and those used to identify the same features in the RI/FS Work Plan, OU-2 FSAP, and this report, a comparative listing is presented in Table 1-9.

Pit 3 can be located on aerial photographs taken between 1940 and 1956, but it is not present on an aerial photograph taken in 1958. Both former Pit 2 and Pit 3 can be seen on the aerial photograph in Figure 1-19.

Pit 1 and Pit 6, as identified in the PA and SI, were not actually "pits" as such, but were open areas where wastes may have been conveniently disposed. Pit 1 (now designated as WP-1) was described as a pit, but it could have been a channel or gully caused by erosion at the location where a 36-inch-diameter storm drain empties into the Arroyo Seco near the south end of Building 103. Spent mercury was reportedly dumped in this area at one time. Pit 6 actually was the location where Richard C. Slade (Slade, 1984) obtained background soil samples from an exploration trench during his investigations at former Buildings 59 and 65.

It was also learned during the interviews that, in the 1940s and 1950s, many buildings at JPL used a cesspool to dispose of sanitary liquid and solid wastes. These cesspools, seepage pits in current terminology, were designed to allow liquid wastes to seep into the surrounding soil. Pits 4 and 5, as identified in the PA and SI, were seepage pits that served former Buildings 59 and 65, respectively. Other information indicated that many of the seepage pits at JPL may have received various quantities of chemical wastes since most of the buildings at JPL either stored or used various chemicals. This new insight on potential contamination sources prompted a diligent search of historical construction drawings for buildings with plumbing connections to seepage pits.

Based on drawings in the microfiche files located in the Facilities Engineering offices, 27 seepage pits were identified by the time the supplemental report (Ebasco, 1990b) for the ESI was completed. A summary of those seepage pits and the buildings to which they were connected are listed in Table 1-10. Most of the older buildings, where seepage pits were used, were located in the northeast section of JPL.

It was later learned that a former salvage storage area located just southeast of existing Building 248 was reportedly used for the disposal of solvents. The area was mistakenly reported, during an interview, as being located near existing Building 144. However, the alleged disposal area is located about 300 feet east of Building 144 and is designated as WP-3 (see Figure 3-1 in Section 3.0). Approximately three 55-gallon drums of solvents at varying concentrations were allegedly dumped into three hand-dug holes every 3 to 4 months over a period of 2 to 3 years during the late 1950s. The holes were approximately 25 feet apart, about 4 feet wide by 3 feet deep, and were acutally located east of former Building 119 that was identified in the aerial photograph included as Figure 1-20.

It was reported that, most likely, the solvents disposed were from cleaning parts and would have been a mixture of trichloroethene, acetone, M50 (trichloroethane), alcohol, and toluene. It was believed that carbon tetrachloride was not in use at JPL during the period of time that the salvage yard was in this area.

The three areas of concern where waste disposal reportedly occurred (Pits 1 and 2 and southeast of Building 248) are represented by the shaded areas in Figure 3-1 (Section 3.0) and are designated WP-1, WP-2, and WP-3, respectively.

Seepage Pit Location Procedures

JPL's Facilities Engineering office maintains all plans, construction drawings, and building records for almost every structure that has been constructed on the laboratory's grounds. Some plans and plan files for certain buildings from the early days are missing. A microfiche file in the Facilities Engineering offices contains negatives for thousands of drawings that have been placed in archive storage. These microfiche can be reviewed rapidly for required information and printed by the microfiche-viewing machine at about one-half scale of the original drawing. It is from this microfiche file, and hard-copy prints from the negatives, that most of the information on the locations, construction details, and uses of the seepage pits has been derived.

Subsequent to preparation of the ESI (Ebasco, 1990a) and prior to completing the Supplemental Information to the ESI report (Ebasco, 1990b), 27 seepage pit or dry well locations were located based on hard-copy drawings and on drawings in the microfiche files at JPL. Thirteen additional seepage pits were identified in the interim period between the supplemental report and completion of the pre-RI draft work plan (Ebasco, 1991).

The procedures used in locating and identifying the seepage pits included the following:

- Review microfiche files for buildings constructed prior to installation of the sewer system (early 1960s).
- Make paper print from microfilm negative for each drawing that may provide information in determining locations of seepage pits.
- Calculate scales of drawings printed from microfiche file.
- Calculate approximate coordinates of seepage pit if drawing (plot plan, grading plan, plumbing plan, building details, etc.) is tied to JPL's coordinate system.
- Transfer location of seepage pit by plotting its approximate coordinates on master map.
- If coordinates are not indicated, enlarge or reduce copy of print for use as an underlay to transfer estimated seepage-pit location to master map by matching preserved reference points.
- When dimensions were shown on printed drawing, the scaled dimensions were used to plot the seepage-pit location on the master map.
- Numbers assigned to the seepage pits are in the order that the pits were discovered, and they were randomly applied when more than one pit appeared on the same drawing.

Based on these procedures, a total of 40 seepage pits (including dry wells) were identified. Information on the seepage pit descriptions (e.g., construction details, piping, drawing numbers, etc.) has not appeared in any of the documents prepared prior to the RI/FS Work Plan (Ebasco, 1993a). The seepage pit designations shown in the text and figures of the RI/FS Work Plan are current designations and are being used throughout the remainder of the project. A detailed description of these pits is provided in Section 3.1.1.

1.3.3.13 Ebasco Environmental (1993c), *"Pre-RI Investigation"* in *Work Plan for Performing a Remedial Investigation/Feasibility Study at the NASA-Jet Propulsion Laboratory*

In anticipation of being placed on the NPL by the EPA, a phased pre-RI investigation was conducted in 1992 that included subsurface explorations at potential contaminant sources originating at seepage pit locations identified earlier (see Section 1.3.3.10). In addition, three shallow monitoring wells and one deep multi-port monitoring well were installed to obtain additional information on the lateral and vertical extent of VOCs in the groundwater beneath JPL. A complete discussion of this investigation is presented in the RI/FS Work Plan (Ebasco, 1993a). Discussions of the pre-RI activities pertaining to the OU-2 RI are summarized below.

A shallow soil-vapor survey was conducted at nine potential contaminant source areas (seepage pits) to evaluate the use of soil-vapor sampling techniques in locating or characterizing seepage-pit locations in a cost-effective manner. It was planned that soil borings would be drilled and sampled at the five potential contaminant source locations having the highest concentrations of VOCs in the soil vapor. The target depth for each sample was 30 feet with an intermediate sample to be collected between 15 to 20 feet. However, a sample would be collected at probe refusal no matter what the depth might be.

Soil-vapor samples were collected at eight seepage pit locations and at another location where a below grade tank had been reported previously. Soil vapor sampling locations are shown in Figure 1-21. Probe refusals caused by cobbles and boulders in the subsurface materials resulted in soil-vapor samples being collected at depths ranging from 6 to 30 feet.

All of the soil-vapor samples collected were subjected to two analyses. The first analysis was conducted according to EPA Method 601 (modified) for specific VOCs standardized for this analysis using direct injection into a gas chromatograph equipped with an electron capture detector. The second analysis was conducted according to EPA Method 602 (modified) for aromatic hydrocarbons using direct injection into a gas chromatograph equipped with a flame-ionization detector (FID). A summary of the VOCs (EPA Method 601) detected in the soil-vapor samples is presented in Table 1-11. Petroleum-based hydrocarbons (EPA Method 602) were not detected in any of the samples.

Based on the results of the soil-vapor analyses, five borings were drilled and soil samples collected for laboratory analysis from seepage pit location Nos. 1, 18, 26, 31, and 35. Each soil boring was drilled with a dual-wall percussion drilling rig using reverse-air circulation. Relatively undisturbed soil samples were collected with a split-spoon sampler for laboratory analysis at approximate 10-foot intervals beginning at a depth of 10 feet below ground surface. Soil Borings 1, 9, 19, 21 were completed to a depth of 100 feet, but soil Boring 12 was terminated at a depth of 88 feet because of mechanical problems. Logs of the soil borings are presented in Appendix A of the RI/FS Work Plan (Ebasco, 1993a). Each boring was backfilled with hydrated bentonite chips. Holes in the asphalt pavement were repaired with a cold-patch asphalt mixture.

Chemical analyses performed on the soil samples were dependent upon the depth within the borehole that each soil sample was collected (Table 1-12). Archived samples were to be analyzed if and for contaminant(s) detected in other samples collected from the same boring. All samples collected from the seepage pit locations were analyzed for VOCs using EPA Method 8240 (including acetone, alcohols, and cyclohexanone), while samples collected from the 30- and 60-foot depths were also analyzed for SVOCs using EPA Method 8270 and for total petroleum hydrocarbons (TPH) using EPA Method 418.1. The soil samples collected at the 20-, 30-, and 60-foot depths were also analyzed for Title 22 metals (Ag, As, Ba, Be, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sb, Se, Tl, V, Zn) and strontium using EPA Methods 6010/7000 series and for mercury (Hg) using EPA Method 245.1. Cyanide was analyzed using EPA Method 9010. Additional analyses were total solids (EPA Method 160.3) to determine percent moisture, laboratory pH (EPA Method 150.1), and nitrate (as N and NO_3) using EPA Method 300.0

Following the sample analysis schedule listed in Table 1-12, soil samples were submitted for organic and inorganic analyses. Organic analytes included VOCs (EPA Method 8240), SVOCs (EPA Method 8270), and TPH (EPA Method 418.1). Forty-six samples were analyzed for volatile organics, 10 samples for semi-volatile organics, and 11 samples for TPH.

Volatile organics were not detected in the 46 samples analyzed. Semi-volatile organics were detected in 2 of 10 samples analyzed. In samples SB1-6-60 (soil boring SB1, 60-foot sample) and SB12-3-30 (soil boring SB12, 30-foot sample) the organic compound was identified as bis(2-etylhexyl) phthalate - a common laboratory contaminant. Concentrations were 0.34 mg/kg and 0.6 mg/kg, respectively. The concentration of the extraneous peak was 0.2 mg/kg. TPH was detected in 1 of 11 soil samples analyzed. The sample, SB1-2-26 (soil boring SB1, 26-foot sample) had a TPH concentration of 59 mg/kg. Analytical results are presented in Table 1-13.

Inorganic analytes included cyanide (EPA Method 9010), Title 22 metals (except mercury) plus strontium (EPA Methods 6010/7000 series), mercury (EPA Method 245.1), percentage moisture versus total solids (EPA Method 160.3), nitrate (as N and NO_3) (EPA Method 300.0), and pH (EPA Method 150.1). Inorganic analytical results are reported in Table 1-14. Twelve samples were analyzed for cyanide, 15 samples for Title 22 metals and strontium, 10 samples for nitrate (as N and NO_3), and 45 samples for percentage moisture versus total solids. Cyanide was detected in 1 of the 12 soil samples analyzed. For sample SB9-3-29.5-30 (soil boring SB9, 29.5- to 30-foot sample), the cyanide concentration was 1.06 mg/kg. Of the 15 samples analyzed for Title 22 metals and strontium, none exceeded the State of California action level for metals. Nitrate (as N) was not detected in any of the samples analyzed. Nitrate (as NO_3) was detected in 3 of 10 samples. Samples SB9-6-60 (soil boring SB9, 60-foot sample), SB12-3-30 (soil boring SB12, 30-foot sample), and SB19-3-30 (soil boring SB19, 30-foot sample), had nitrate (NO_3) concentrations of 1.6 mg/kg, 1.0 mg/kg, and 1.1 mg/kg, respectively. Percentage moisture versus total solids ranged between 2 percent in SB21-1-10 (soil boring SB21, 10-foot sample) to 13 percent in sample SB21-8-100 (soil boring SB21, 100-foot sample). Soil pH for the soil samples ranged between 4.7 in SB1-1-10 (soil boring SB1, 10-foot sample) to 8.1 in sample SB19-1-10Dup (soil boring SB19, 10-foot duplicate sample).

1.3.3.14 U.S. Environmental Protection Agency (1993), *Aerial Photographic Analysis of the NASA Jet Propulsion Laboratory, Pasadena, California*

A historical aerial photographic analysis of the Jet Propulsion Laboratory study area was conducted by the U.S. Environmental Protection Agency (EPA) using steroscopic pairs of selected aerial photographs spanning the period from 1941 through 1992 to identify potential waste-disposal units such as impoundments, trenches, and pits. The results of this analysis is summarized in the following paragraph taken from EPA's report:

> "The 1941 photograph revealed the study area, before the establishment of the Jet Propulsion Laboratory facilities, consisted of cultivated cropland, an equestrian park, and undeveloped rangeland. By 1946, Explorer Road was paved for vehicle access and several laboratory and test buildings had been constructed. Probable waste disposal structures including a pit, trench, and an impoundment were noted in the southeast portion of the facility adjacent to the Seco Arroyo in 1952; however, no waste disposal activity was noted at the pit, trench, or impoundment by 1964. These structures were not visible in 1972 due to the construction of a large parking lot. Additional construction of more laboratories and support buildings was observed throughout the facility on 1977, 1980, 1985, 1989, and 1992 photographs; however, no visible signs of leachate seepage, cesspool seepages, or seepages from waste disposal units were observed."

EPA (1993, Figure 5) identified a long, concrete-lined pool filled with liquid in the southeastern portion of the study area on a black and white photograph dated February 27, 1946, and that a dark-toned material (possibly sludge) was placed on the south side of the long pool.

EPA determined that the pool was possibly a test facility structure because of its close proximity to other laboratory buildings. In actuality, this water-filled structure was Building 45 and originally named "Towing Channel." In later years, the structure was referred to as "torpedo tube," "aerodynamics laboratory," and "impact laboratory." The primary initial use of the structure was for the research and development of guidance systems. The dark-toned area on the south side of Building 45 is due to vegetation that can be seen on the oblique, low altitude JPL photograph JB358G dated July 2, 1947 (Figure 1-22). Ground-covering vegetation, as well as circular tree-irrigation rings, can be seen on the slope south of the Towing Channel in Figure 1-17.

From a black and white aerial photograph dated August 15, 1952, EPA (1993, Figure 6) identified a circular impoundment, designated as Annotation G near the southeast portion of the study area. This graded depression in the Arroyo Seco is WP-1, which is discussed in Section 1.3.3.12 and shown in Figure 1-17.

Two trenches identified by the EPA (1993, Figure 7) on a black and white aerial photograph dated November 17, 1952, were designated as Annotations H and I during their analysis. It was suggested by the EPA that these two trenches, located in the southeast part of the study area adjacent to the Arroyo Seco, may represent waste-disposal activities. Since both trenches were outside the JPL boundary at the time the aerial photograph was taken and neither trench was part of the JPL's operations, historical information on their use and contents is not available. Based on the aerial photograph and the locations of significant monuments, it is believed that part of Annotation H and all of Annotation I is covered by the parking lot along the southeast boundary of the JPL facility. These two potential contaminant source areas (Annotations H and I) have been redesignated as Waste Pit Nos. WP-4 and WP-5, respectively, for the OU-2 RI, and their locations are shown in Figure 3-1, Section 3.0.

1.3.4 Additional Documents

Work conducted during the course of the RI for OU-2 began in 1994 and continued through 1998. The Work Plan for the OU-2 RI (Ebasco, 1993a) was originally presented in December 1993 as a document that addressed the work to be conducted under the RI and FS for all three operable units at JPL. As work progressed on the OU-2 RI, the Work Plan and the Field Sampling and Analysis Plan (FSAP) (Ebasco, 1993d) evolved to address additional sampling required to more accurately investigate contaminant sources and the nature and extent of contamination in on-site soil. Addenda to the Work Plan and FSAP were developed and approved to address supplemental investigations and include the following documents:

- *Draft Final "Part A" Addendum to the Work Plan for Performing a Remedial Investigation/Feasibility Study*, prepared for the National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadena, California, by Foster Wheeler Environmental Corporation, September 1996 (FWENC, 1996a).
- *Draft Final "Part B" Addendum to the Work Plan for Performing a Remedial Investigation/Feasibility Study*, prepared for the National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadensa, California, by Foster Wheeler Environmental Corporation, September 1996 (FWENC, 1996b).
- *Draft Final Addendum Number 2 to the Work Plan for Performing a Remedial Investigation/Feasibility Study*, prepared for the National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadensa, California, by Foster Wheeler Environmental Corporation, May 1998 (FWENC, 1998a).
- *Draft Final "Part A" to the Field Sampling and Analysis Plan (FSAP) for Performing a Remedial Investigation at Operable Unit 2: Potential On-Site Contaminant Source Areas*, prepared for the National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadensa, California, by Foster Wheeler Environmental Corporation, September 1996 (FWENC, 1996c).

- *Draft Final "Part B" to the Field Sampling and Analysis Plan (FSAP) for Performing a Remedial Investigation at Operable Unit 2: Potential On-Site Contaminant Source Areas*, prepared for the National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadensa, California, by Foster Wheeler Environmental Corporation, September 1996 (FWENC, 1996d).
- *Draft Final Addendum Number 2 to the Field Sampling and Analysis Plan (FSAP) for Performing a Remedial Investigation at Operable Unit 2: Potential On-Site Contaminant Source Areas*, prepared for the National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadensa, California, by Foster Wheeler Environmental Corporation, May 1998 (FWENC, 1998b).

In addition to the Work Plan and FSAP, and the associated addenda, the Quality Assurance Program Plan (QAPP) (Ebasco, 1993e) provides project-specific data quality objectives (DQOs) for the RI and was subsequently revised to address supplemental investigations for OU-2. The revised QAPP includes the following document:

- *Draft Final Addendum to the Quality Assurance Program for Performing a Remedial Investigation*, prepared for the National Aeronautics and Space Administration Jet Propulsion Laboratory, Pasadensa, California, by Foster Wheeler Environmental Corporation, September 1996 (FWENC, 1996e).

TABLE 1-1

ANALYTICAL RESULTS OF SOIL SAMPLES COLLECTED BY R.C. SLADE

Sample ID	PH (units)	Chromium (mg/kg	Fluoride (mg/kg)	Qualitative Metals Test	Semiquantitative Analysis (Results in percent)		
					Element	TP1 at 6 ft	TP2 at 7 ft
TP-2 @ 1 ft	7.1	11	NA	ND	Silicon	23.%	22.%
TP-2 @ 4 ft	7.5	9	NA	TR	Iron	3.7	4.1
TP-2 @ 7 ft	7.2	7.3	135	positive	Aluminum	9.8	11.
TP-1 @ 6 ft	7.6	NA	NA	positive	Calcium	4.6	3.5
TP-3 @ 3 ft	7.8	6	NA	TR	Sodium	2.9	4.5
TP-3 @ 4.5 ft	8.3	7.4	NA	ND	Potassium	2.1	3.0
TP-3 @ 5 ft	8.1	5.8	NA	ND	Magnesium	0.96	0.66
TP-3 @ 7 ft	7.8	9	184	ND	Manganese	0.034	0.057
TP-4 @ 6 ft	7.8	4.8	142	ND	Barium	TR<0.10	TR<0.10
TP-5 @ 5 ft	7.9	NA	NA	ND	Titanium	0.64	0.53
TP-6 @ 1.5 ft	7.5	7.3	NA	ND	Lead	ND<0.02	TR<0.02
TP-7 @ 1.5 ft	8.1	6	NA	ND	Gallium	0.0064	0.0085
TP-7 @ 2.5 ft	8	5	NA	ND	Vanadium	0.010	0.015
TP-7 @ 8 ft	7.6	29	340	ND	Copper	0.0020	0.0024
TP-7 @ 9.5 ft	7.7	7.2	270	ND	Nickel	TR<0.001	TR<0.001
TP-8 @ 1.5 ft	8.1	5.2	NA	TR	Zirconium	0.050	0.023
TP-8 @ 4 ft	8	NA	NA	ND	Cobalt	0.0028	TR<0.002
					Strontium	0.046	0.057
					Chromium	0.0063	0.0082
					Other elements	nil	nil

Notes:

mg/kg - Milligrams per kilogram.
ft - Feet.
TP - Test pit.
NA - Not analyzed.
ND - Not detected.
TR - Trace.
Reference: Slade, 1984.

TABLE 1-2

RELATIVE RANKING OF VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL-VAPOR SURVEY

Wire Number	Collector Type	BTEX	TCA	Freon 11 or 113	TCE	PCE	Chloroform
1	S	I	-	-	-	Negligible	-
2,3	D	V. Low	V. Low	V. Low	-	Negligible	-
4,5	D	I	-	-	-	Negligible	-
6,7	D	V. Low	V. Low	V. Low	-	Negligible	-
8	S	I	-	-	-	Low	-
9	S	V. Low	V. Low	V. Low	-	V. Low	-
41	S,T	NA	-	-	-	Negligible	-
42	S,T	NA	-	-	-	V. Low	-
10,11	D	V. Low	V. Low	-	-	V. Low	-
12	S	V. Low	V. Low	-	-	Negligible	-
13	S	V. Low	-	V. Low	-	Negligible	-
15,16	D	V. Low	V. Low	V. Low	-	V. Low	-
17	S	I	-	-	-	Negligible	-
18	S	I	V. Low	-	-	V. Low	-
43	S,T	NA	-	-	-	V. Low	-
44	S,T	NA	-	-	-	Moderate	-
19	S	V. Low	V. Low	V. Low	-	V. Low	-
20,21	D	Low	-	Moderate	-	Moderate	-
22	S	V. Low	-	V. Low	-	V. Low	-
23	S	V. Low	-	V. Low	-	V. Low	-
24,25	D	V. Low	V. Low	V. Low	-	Moderate	-
45	S,T	NA	V. Low	-	-	Moderate	-
46	S,T	NA	V. Low	Low	V. Low	Moderate	-
26,27	D	V. Low	V. Low	-	-	Negligible	-
28	S	V. Low	V. Low	V. Low	V. Low	V. Low	-
30,31	D	Low	-	-	-	Low	Moderate
32	S	V. Low	-	V. Low	-	Low	-
33	S	V. Low	Low	V. Low	-	Moderate	-
34	S	V. Low	V. Low	V. Low	V. Low	Negligible	-
35,36	D	V. Low	Low	-	V. Low	Negligible	-
37	S	V. Low	V. Low	V. Low	V. Low	Negligible	V. Low
38	S	V. Low	V. Low	V. Low	-	Negligible	-
39	S	V. Low	Moderate	V. Low	Moderate	Moderate	-
40	S	Moderate	-	-	High	V. Low	-

Notes:

Analyses are grouped according to location at the JPL site.
S = Single wire in one culture tube.
D = Double wires in one culture tube.
T = Time trial sample.
I = Interference from natural organic materials emitted from confiers.
Negligible - for PCE only.
NA = Analyte not investigated.
\- = Below detection limit.
Reference: Ebasco, 1990a.

TABLE 1-3

ANALYTICAL RESULTS OF SURFACE SEDIMENT SAMPLES COLLECTED IN THE ARROYO SECO

(Sample Locations Shown in Figure 1-11)

Constituent	Units	Sample Number					Regulatory Limits	
		SD-01	SD-01D	SD-02	SD-03	SD-04	TTLC (mg/kg)	STLC (mg/L)
Metals								
Barium	mg/kg	23	22	41	75	75	10,000	100
Beryllium	mg/kg	ND	ND	ND	ND	0.56	75	0.75
Cadmium	mg/kg	0.5	ND	0.76	1.2	1.2	100	1
Chromium (total)	mg/kg	2.8	2.8	4.6	8.0	8.4	2,500	560
Cobalt	mg/kg	2.6	2.5	3.9	7.2	7.3	8,000	80
Copper	mg/kg	5.3	5.3	13	18	16	2,500	25
Lead	mg/kg	16	5.5	15	36	26	1,000	25
Mercury	mg/kg	ND	ND	ND	0.13	0.12	20	0.2
Nickel	mg/kg	1.2	ND	3.4	4.5	4.3	2,000	20
Vanadium	mg/kg	6.3	5.6	9.6	18	19	2,400	24
Zinc	mg/kg	18	16	37	69	48	5,000	250
Strontium	mg/kg	20	21	21	61	56	NR	NR
Cyanide	mg/kg	ND	ND	ND	ND	0.4	NR	NR
Total Petroleum Hydrocarbons	mg/kg	ND	14	71	56	19	NR	NR

Notes:

TTLC - Total Threshold Limit Concentrations, California Code of Regulations, Title 22.
STLC - Soluble Threshold Limit Concentration, California Code of Regulations, Title 22.
mg/kg - Milligrams per kilogram.
mg/L - Milligrams per liter.
ND - Not detected.
NR - Not regulated.
Reference: Ebasco, 1990b.

TABLE 1-4

ANALYTICAL RESULTS OF SOIL SAMPLES COLLECTED AS PART OF THE HRS

(Sample Locations Shown in Figure 1-13)

Constituent	Units	Sample Number					Regulatory Limits	
		SS-01	SS-02	SS-02D	SS-03	SS-04	TTLC (mg/kg)	STLC (mg/L)
Metals								
Barium	mg/kg	170	78	110	31	30	10,000	100
Cadmium	mg/kg	1.2	ND	0.65	0.71	0.62	100	1.0
Chromium (total)	mg/kg	2.6	2.3	2.6	4.9	2.7	2,500	560
Cobalt	mg/kg	8.5	4.7	5.6	3.6	2.7	8,000	80
Copper	mg/kg	6.1	6.0	6.3	7.0	5.2	2,500	25
Lead	mg/kg	ND	4.9	8.0	11	ND	1,000	25
Nickel	mg/kg	1.8	1.8	1.9	2.2	1.1	2,400	20
Vanadium	mg/kg	15	7.5	11	6.8	5.9	2,400	24
Zinc	mg/kg	45	33	29	69	18	5,000	250
Strontium	mg/kg	21	14	19	13	20	NR	NR
Total Petroleum Hydrocarbons	mg/kg	ND	12	ND	29	ND	NR	NR

Notes:

TTLC - Total Threshold Limit Concentrations, California Code of Regulations, Title 22.
STLC - Soluble Threshold Limit Concentration, California Code of Regulations, Title 22.
mg/kg - Milligrams per kilogram.
mg/L - Milligrams per liter.
ND - Not detected.
NR - Not regulated.
Reference: Ebasco, 1990b.

TABLE 1-5

SUMMARY OF DETECTED CHEMICAL COMPOUNDS IN SOIL SAMPLES FROM STORM DRAIN CATCH BASIN

Analysis	Concentration (mg/kg)	EPA Method
Volatile Organic Compounds:		8240
Acetone	335	
Methylene Chloride	834	
Carbon Disulfide	27	
1,1-Dichloroethane	51	
2-Butanone (MEK)	113	
cis-1,2-Dichlorethene	66	
Chloroform	720	
1,2-Dichloroethane	28	
Carbon Tetrachloride (CCl_4)	13,400 (estimated)	
Trichloroethene (TCE)	55	
Toluene	27	
Tetrachloroethene (PCE)	23	
Chlorobenzene	28	
Total Xylenes	76	
Styrene	34	
Semi-Volatile Organic Compounds:		8270
1,4-Dichlorobenzene	9.9	
1,2-Dichlorobenzene	4.6	
Napthalene	5.1	
Di-n-butylphtalate	9.2	
Metals:		
Arsenic	1.8	7061
Cadium	7.3	6010
Chromium (total)	124	6010
Copper	251	6010
Lead	125	6010
Mercury	34	7470
Nickel	724	6010
Zinc	636	8010
Cyanide	0.54	8010
Total Petroleum Hydrocarbons (gasoline)	4,640	8015 (Modified)
Pesticides and PCBs	None Detected	8080

Reference: Jet Propulsion Laboratory, 1990.

TABLE 1-6

SEEPAGE PIT DESIGNATIONS AND INFERRED USE

Seepage Pit No.	Associated Building No.	Building Still Exists (Yes/No)	Current Area Use	Inferred Use
1 & 2	3, 4, 17, 19, 22	No No	Parking lot north of Building 11.	Pits connected in tandem and located in area having oldest use-history on JPL site; recent discovery of solvents and other contaminants in nearby seepage pit that was uncovered during construction work in 1990.
3 & 4	11	Yes	Planter west and north of Building 11, respectively.	Pits connected in tandem; Building 11 housed plumbing and electrical shops where solvents may have been used.
5	68, 71, 127	No	Lawn east of Building 277.	Original uses of Buildings 68 and 127 are not known; Building 71 was used as "mechanics stores." Buildings are located near old solid propellant bunkers and may have been used to store solvents used in mixing and developing propellants.
6	Unknown		Mariner Road.	Implications are similar to those for Seepage Pit Nos. 1, 2, 3, 4, and 5.
7, 7A & 7B	103	Yes	Under Building 103. Under electrical substation on south side of Building 103.	Building housed machine shop, fabrication shop, and metal pickling room; solvents used for cleaning and degreasing; alleged dumping of liquids in "drain hole" near southeast corner of building.
8 (DW)	65	No	Under Building 302.	Dry well plumbed to collect liquids originating from pit in building's floor where universal testing machine was located.
9	13 or 44	No	Under Building 302.	True location of pit is questionable; may have been connected to Building 13, which housed a small workshop, or the old Credit Union Building 44.
10	78	Yes	Under retaining wall foundation and bank of nitrogen gas tanks.	Building 78 housed a hydraulics laboratory; solvents commonly used to clean machinery and degrease parts.
11	101, 104	No	At base of slope near retaining wall north of Building 113.	Collected sanitary wastes from transportation offices (Building 101) and First Aid Building 104. Potential for disposal of solvent or hydrocarbon wastes from Building 101.
12	74	No	Planter area south of Building 78.	Chemistry test cell (liquid propellants); solvents reportedly used for cleaning and degreasing; disposal of chemicals reported to have occurred by pouring into drains.

TABLE 1-6

SEEPAGE PIT DESIGNATIONS AND INFERRED USE

Seepage Pit No.	Associated Building No.	Building Still Exists (Yes/No)	Current Area Use	Inferred Use
13 & 13A	65	No	Under Building 302.	Materials laboratory; may have housed machinery and metals cleaned with solvents; also housed chemistry laboratory; bottom of pit in building for universal testing machine drained to dry well.
14	46	No	Under entryway to Building 302.	Shop for liquid propellant test cell; implications are same as those for Seepage Pit Nos. 12 and 15.
15	34	No	Adjacent to or under foundations of Building 300.	Shop building associated with old test cell buildings (Test Cell "F") and liquid testing facility; spilled solvents reportedly small, but did occur on regular basis over several years.
16	59	No	North end of elevated patio on east side of Building 303.	Building housed old paint shop; high potential for paint solvents having been disposed in seepage pit serving facility.
17	55	No	Parking lot near Building 280.	Solid propellant mixing facility; solvents used to clean mixing hardware were disposed by pouring into sumps prior to installation of sanitary sewer system.
18 & 19	90	Yes	Under Pioneer Road.	Shop for test cell No. 51 (solid propellant testing in Test Cell "X"); test motors and hardware soaked in tubs of solvents (included carbon tetrachloride and acetone) that were not recycled and allegedly dumped into sumps on west side of Building 90 or at east end of solid propellant preparation area (east of Building 88).
20 & 21	63	No	Under or behind retaining wall foundations.	Compressors and maintenance shop; solvents routinely used for parts cleaning.
22	80	No	Under office trailers.	Wind tunnel building; no history of solvent or chemical usage.
23 & 24, 25	67	Yes	Parking area along Explorer Road. Beneath walkway at top of slope.	Building's history is diverse. Although mainly an office building, several small laboratories (biology, kinetics, low-level radioactive, and spectroscopy) were located within the structure over a several-year period--possibly before connections made to sanitary sewer system.

TABLE 1-6

SEEPAGE PIT DESIGNATIONS AND INFERRED USE

Seepage Pit No.	Associated Building No.	Building Still Exists (Yes/No)	Current Area Use	Inferred Use
26 & 28	77	No	Under Building 299. In planter or under Pioneer Road.	Structure housed experimental chemistry lab and fluorine propellant test cell with an acid-neutralizing pit constructed similar to a dry well; numerous chemicals reportedly disposed by dumping into available sumps near building. Seepage pit is upgradient from monitoring well MW-7.
27 (DW)	246	Yes	Asphalt paved parking area.	Dry well from sink at former soils test laboratory; no history of solvent or chemical usage.
29	32	No	Asphalt paved parking lot.	Test cell used for liquid propellant testing since mid-1950s; solid propellants used during late 1940s. Seepage pit located near area where ongoing construction work disclosed solvent contamination in storm-drain catch basin and previously unknown seepage pit.
30	117	Yes	Asphalt paved parking area.	Building housed former solid propellant test cell where solvents used to clean rocket motors and hardware; solvents reportedly not recycled and disposed of by dumping into nearby drains and sumps.
31	12(?) 107, 112	No Yes	Asphalt paved driveway.	Both buildings contained propellant test cells; solid propellants may have been used during early history of buildings, along with solvents associated with solid propellant clean up. Building 107 later converted to plasma flow research laboratory. Implications are similar to the same rationale for boring reference No. 19.
32	86	Yes	Under walkway at top of steep slope on south side of Building 86.	Seepage pit near east end of solid propellant preparation area and adjacent to Building 86; pits (sumps) in area reportedly used to dispose of solvents.
33	97	Yes	Asphalt paved driveway.	Development laboratory for solid propellant chemistry experimentation; solvents used to clean laboratory hardware; all sink drains led to seepage pit; a sump or dry well at west end of building reportedly used for solvent disposal.

TABLE 1-6

SEEPAGE PIT DESIGNATIONS AND INFERRED USE

Seepage Pit No.	Associated Building No.	Building Still Exists (Yes/No)	Current Area Use	Inferred Use
34	98	Yes	Asphalt paved driveway.	Seepage pit at east end of solid propellant preparation area (Buildings 86, 87, 88, 89, and 98); pit reportedly used for disposal of carbon tetrachloride, methyl ethyl ketone, trichloroethylene, cyclohexanone (?), and other chemicals after sewer system installed.
35	81	No	Asphalt paved parking lot.	Building housed workshops, storage rooms, and offices. Seepage pit located in same area where solvents and other chemicals discovered in soil during ongoing construction. (See rationale for boring reference Nos. 19 and 20.)
36	Unknown		Asphalt paved driveway.	Storm drain catch basins removed during ongoing construction were contaminated with carbon tetrachloride, acetone, chloroform, trichloroethylene, and mercury; sump tanks (leakages reported), dilution chambers, and seepage pits, associated with test cells and shops, existed along north side of Jato Road).
37 (DW)	2	No	Under Explorer Road.	Dry well for drain from building has unknown use, but implications are same as those for Seepage Pit Nos. 1, 2, 3, 4, 35, and 36.
NA	197	Yes	Asphalt paved driveway.	1,000-gallon tank (possible leakage) reportedly located at west end of building; propellant grindings and solvents reportedly dumped into tank at frequent intervals.

Notes:

NA – Not applicable.
DW – Dry well.
Reference: Ebasco, 1991.

TABLE 1-8

ANALYTICAL RESULTS FOR SOIL TEST-BORING INVESTIGATION, BUILDING 306 EXCAVATION

SAMPLE ID	EPA 418.1	8015 M DIESEL	EPA 8020/BTEX
D 6 A - 3'	25	-	-
D 6 A - 5'	7	-	-
D 6 B - 3'	27,000	140	ND
D 6 B - 5'	26	-	-
D 6 C - 3'	750	ND	ND (*)
D 6 C - 5'	56	ND	ND
D 6 C - 10'	ND	-	-
D 6 D - 3'	480	ND	ND
D 6 D - 5'	410	ND	ND
D 6 D - 10'	36	-	-
D 8 A - 3'	15	-	-
D 8 A - 5'	5.3	-	-
D 8 B - 3'	670	ND	ND
D 8 B - 5'	12	-	-
D 8 C - 3'	1,200	ND	ND (**)
D 8 C - 5'	550	ND	ND
D 8 C - 10'	9.2	-	-
D 10 A - 3'	ND	ND	ND
D 10 A - 5'	21	ND	ND
D 10 A - 10'	ND	-	-
D 10 A - 15'	ND	-	-
D 10 A - 20'	ND	-	-
D 10 B - 3'	10,000	99	ND
D 10 B - 5'	15	-	-
D 10 C - 3'	1,000	ND	ND
D 10 C - 5'	34	-	-
D 13 A - 3'	ND	ND	ND
D 13 A - 5'	ND	ND	ND
D 13 A - 10'	ND	-	-
D 13 A - 15'	ND	-	-
D 13 A - 20'	ND	-	-
D 13 B - 3'	41	-	-
D 13 B - 5'	30	-	-
D 13 C - 3'	1,500	ND	ND
Detection Limit	5.0 mg/kg	20 mg/kg	0.1 mg/kg

SAMPLE ID	EPA 418.1	8015 M DIESEL	EPA 8020/BTEX
D 13 C - 5'	690	ND	ND
D 13 C - 10'	ND	-	-
D 15 A - 3'	300	ND	ND
D 15 A - 5'	43	ND	ND
D 15 A - 10'	37	-	-
D 15 A - 15'	ND	-	-
D 15 A - 20'	ND	-	-
D 15 B - 3'	ND	-	-
D 15 B - 5'	ND	-	-
D 15 C - 3'	430	ND	ND
D 15 C - 5'	16	-	-
D 17 A - 3'	ND	ND	ND
D 17 A - 5'	ND	ND	ND
D 17 A - 10'	ND	-	-
D 17 A - 15'	ND	-	-
D 17 A - 20'	ND	-	-
D 17 B - 3'	250	ND	ND
D 17 B - 5'	140	ND	ND
D 17 B - 10'	ND	-	-
D 17 C - 3'	260	ND	ND
D 17 C - 5'	ND	-	-
D 17 D	NR	NR	NR
D 17 E - 3'	580	ND	ND
D 17 E - 5'	12	-	-
D 20 A - 3'	20	-	-
D 20 A - 5'	ND	-	-
D 20 B - 3'	1,300	ND	ND
D 20 B - 5'	19	-	-
D 1 - 3'	5,500	94	ND
D 1 - 5'	ND	ND	ND
D 1 - 10'	ND	-	-
D 1 - 15'	ND	-	-
D 2 - 3'	110	ND	ND
D 2 - 5'	250	ND	ND
D 2 - 10'	6.1	-	-
D 2 - 15'	ND	-	-
Detection Limit	5.0 mg/kg	20 mg/kg	0.1 mg/kg

SAMPLE ID	EPA 418.1	8015 M DIESEL	EPA 8020/BTEX
D32B E-1 3'-4'	ND	-	-
D32B E-2 8'-9'	ND	-	-
D32B E-3 13'-14'	ND	-	-
D37C E-1 6'-7'	120	-	-
D37C E-2 10'-11'	ND	-	-
D37C E-3 19'-20'	ND	-	-
D42E E-1 3'-4'	470	ND	ND
D42E E-2 5'-6'	330	ND	ND
D42E E-3 9'-10'	ND	-	-
D45F E-1 3'-4'	180	ND	ND
D45F E-2 7'-8'	ND	-	-
D45F E-3 13'-14'	ND	-	-
D48G E-1 3'-4'	71	-	-
D48G E-2 7'-8'	100	-	-
D48G E-3 12'-13'	ND	-	-
Detection Limit	10 mg/kg	10 mg/kg	0.005 mg/kg (BTE) 0.015 mg/kg (X)

NOTE:
ND = none detected
NR = no sample recovery
- = not analyzed
mg/kg = milligram per kilogram
BTEX = benzene, toluene, ethylbenzene, total xylenes
(*) = 0.15 mg/kg toluene
(**) = 0.1 mg/kg toluene

Reference: Maness, 1992.

TABLE 1-7

ANALYTICAL RESULTS FOR CONTAMINANT CHARACTERIZATION, COMPOSITE SOIL SAMPLE FROM BUILDING 306 EXCAVATION

Analysis	Concentration (mg/kg)	EPA Method
Total petroleum hydrocarbons	180	418.1
Volatile organic compounds	ND	8240
Semi-volatile organic compounds	ND	8270
Pesticides and PCBs	ND	8080A
Cyanide	ND	335.2
Title 22 Metals:		
Antimony	0.95	6010
Arsenic	0.22	7060
Barium	120	6010
Beryllium	0.58	6010
Cadmium	ND	6010
Chromium	11	6010
Cobalt	11	6010
Copper	30	6010
Lead	14	6010
Mercury	0.10	7471
Molybdenum	0.50	6010
Nickel	8.1	6010
Silver	ND	6010
Thallium	ND	6010
Vanadium	43	6010
Zinc	66	6010
TCLP volatile organics	ND	8240
TCLP semi-volatile organics	ND	8270
Bioassay toxicity test	Non-Hazardous	

Notes:

mg/kg - Milligrams per kilogram.
ND - Not detected.
Reference: Maness, 1992.

TABLE 1-9

COMPARISON OF PIT NUMBERS USED IN VARIOUS DOCUMENTS

Pit Description	Slade (1984)	PA and SI (Ebasco, 1988a and 1988b)	ESI Report (Ebasco, 1990a)	Supplement to ESI (Ebasco, 1990b)	Draft Pre-RI Work Plan (Ebasco, 1991)	RI/FS Work Plan (Ebasco, 1993a)	OU-2 FSAP (Ebasco, 1993d)	OU-2 RI Report (This Document)
Erosion gully (?) near Building 103	N/A	1	1	1	N/A	WP-1	WP-1	WP-1
Graded depression in Arroyo Seco	N/A	2	2	2	N/A	WP-2	WP-2	WP-2
Pit at Building 299	N/A	3	3	3	28	28	28	28
Seepage pit at Building 59	2,3,4,5*	4	4	4	16	16	16	16
Seepage pit at Building 65	6,7,8*	5	5	5	13	13	13	13
Background sampling location near Building 97	1	6	6	6	N/A	N/A	N/A	N/A
Hand-dug pits southeast of Building 248	N/A	N/A	N/A	N/A	N/A	WP-3	WP-3	WP-3

Notes:

N/A - Not applicable.

* Exploration trench numbers.

Reference: Ebasco, 1993b.

TABLE 1-10

SEEPAGE PIT NUMBERS AND ASSOCIATED BUILDINGS

Seepage Pit No.	Building Number	Building Name
1,2	3	Superintendent of Mechanics' Office
1,2	4	Mechanics' Assembly Shop
3,4	11	Electrical and Plumbing Shops and Stores
9	13	Offices, Lab and Shop
1,2	17	Lunch Counter
1,2	19	Restrooms
1,2	22	Thermocouple Lab
15	34	Shop-test Cell #33 (Liquid Propellants)
9	44	Credit Union
14	46	Shop-test Cell #42 (Liquid Propellants)
18,19	52	Test Cell "X" Observation Building
17	55	Solid Propellant Mixing Lab
16	59	Paint Shop
20,21	63	Ramjet Shop
8,13	65	Materials Lab
23,24,25	67	Engineering Building and Labs
5	68	Electric and Plumbing Shop
5	71	Mechanics Stores
12	74	Chemistry Test Cell
26	77	Experimental Chemistry Lab
10	78	Hydraulics Lab
18,19	90	Shop-test Cell #51 (Solid Propellants)
11	101	Transportation Offices and Shop
7	103	Fabrication Shop and Inspection
11	104	First Aid and Fire Department
27	246	Soils Test Lab
6	*	*
22	*	*

Notes:

* Currently unknown.

Source: Facilities Engineering microfiche and drawing files at JPL.

Reference: Supplemental Information to the ESI Report (Ebasco, 1990b).

TABLE 1-11

SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN SOIL-VAPOR SAMPLES (April 1992)

Seepage Pit Number	Soil Boring Number	Soil-Vapor Sample Number	Sample Depth (feet)	Carbon tetrachloride	Chloroform	1,1-dichloroethene	1,1,1-trichloroethane	Trichloro-ethylene
				Concentrations in micrograms per liter (μg/L)				
1	1	6	10.5	54	1.0	1.5	ND	ND
18,19	9	4S	20	ND	ND	29	ND	ND
	9	4D	30	ND	ND	44	ND	ND
26	12	10	10.5	ND	ND	4.6	ND	ND
30	14	3	27-30	ND	ND	1.4	ND	ND
33	15	9S	20	ND	ND	1.2	ND	ND
34	16A	8	6	ND	ND	ND	1.5	ND
NA	18	7S	21-24	ND	ND	ND	ND	ND
31	19	11	12	7,928	20	ND	ND	2.2
31	19	12	19	5,076	17	ND	ND	1.4
35	21	5S	15	218	2.7	1.4	ND	ND

Notes:

ND – Not detected (or below detection limit of 1.0 μg/L).

NA – Not applicable.

Reference: Ebasco, 1993a.

TABLE 1-12

SEEPAGE PIT SOIL SAMPLE ANALYSIS SCHEDULE
(October 1992)

Depth (feet)	VOCs EPA 8240*	Semi-VOCs EPA 8270	TPH EPA 418.1	Title 22 Metals and Strontium SW-846 6010/7000	Cyanide EPA 9010
10	X				
20	X			X	X
30	X	X	X	X	X
40	X			Archive	Archive
50	X			Archive	Archive
60	X	X	X	X	X
70	X			Archive	Archive
80	X			Archive	Archive
90	X			Archive	Archive
100	X			Archive	Archive

Notes:

* Including Acetone and Alcohols plus Cyclohexanone.

Reference: Ebasco, 1993a.

TABLE 1-13

SUMMARY OF ORGANIC CHEMICAL ANALYSES PERFORMED ON SOIL SAMPLES
(October 1992)

Sample Designation	Volatile Organics EPA 8240	Semi-Volatile Organics EPA 8270		Total Petroleum Hydrocarbons EPA 418.1
SB1-1-10*	ND	ND		ND
SB1-2-26	ND	--		59
SB1-5-50	ND	--		--
SB1-6-60	ND	bis(2-ethylhexyl) phthalate	0.34	ND
SB1-7-69	ND	--		--
SB1-8-79	ND	--		--
SB1-9-89.5	ND	--		--
SB1-10-99.5	ND	--		--
SB9-1-10	ND	--		--
SB9-2-20	ND	--		--
SB9-3-29.5	ND	ND		ND
SB9-4-45	ND	--		--
SB9-6-60	ND	ND		ND
SB9-7-70	ND	--		--
SB9-8-80	ND	--		--
SB9-9-90	ND	--		--
SB9-10-100	ND	--		--

TABLE 1-13

SUMMARY OF ORGANIC CHEMICAL ANALYSES PERFORMED ON SOIL SAMPLES (October 1992)

Sample Designation	Volatile Organics EPA 8240	Semi-Volatile Organics EPA 8270		Total Petroleum Hydrocarbons EPA 418.1
SB12-1-10	ND	--		--
SB12-2-20	ND	--		--
SB12-3-30	ND	bis(2-ethylhexyl) phthalate	0.6	ND
SB12-4-40	ND	--		--
SB12-4-40 Dup	ND	--		--
SB12-5-50	ND	--		--
SB12-6-60	ND	ND		ND
SB12-7-70	ND	--		--
SB12-8-80	ND	--		--
SB12-9-87	ND	--		ND
SB19-1-10	ND	--		--
SB19-1-10 Dup	ND	--		--
SB19-2-18	ND	--		--
SB19-2-18 Dup	ND	--		--
SB19-3-30	ND	(one) unknown scan #1815	0.2	ND
SB19-4-38	ND	--		--
SB19-5-50	ND	--		--
SB19-6-60	ND	ND		ND

TABLE 1-13

SUMMARY OF ORGANIC CHEMICAL ANALYSES PERFORMED ON SOIL SAMPLES
(October 1992)

Sample Designation	Volatile Organics EPA 8240	Semi-Volatile Organics EPA 8270	Total Petroleum Hydrocarbons EPA 418.1
SB19-7-70	ND	--	--
SB19-8-80	ND	--	--
SB19-9-90	ND	--	--
SB21-1-10	ND	--	--
SB21-2-20	ND	--	--
SB21-3-30	ND	ND	ND
SB21-4-60	ND	ND	ND
SB21-5-75	ND	--	--
SB21-6-80	ND	--	--
SB21-7-90	ND	--	--
SB21-8-100	ND	--	--

Notes:

All results noted in mg/kg unless reported otherwise.
ND - Not detected.
-- Not analyzed.
* - Sample Designation:
SB1 - Soil boring number.
1 - Sample number.
10 - Depth, in feet, at which sample was collected.
Reference: Ebasco, 1993a.

TABLE 1-14

SUMMARY OF INORGANIC CHEMICAL ANALYSES PERFORMED ON SOIL SAMPLES
(October 1992)

Sample	Metals																					
	Ag	As	Ba	Be	Cd	Co	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Sr	Tl	V	Zn	CN	N	NO_3	Percentage Moisture[1]	Lab pH
TTLC	500	500	10,000	75	100	8,000	500	2,500	20	3,500	2,000	1,000	500	100	-	700	2,400	5,000	-	-	-	-	-
STLC	5	5	100	0.75	1	80	560	25	0.2	350	20	5	15	1	-	7	24	250	-	-	-	-	-
SB1-1-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4.7
SB1-2-26	ND	ND	43	ND	ND	ND	7.2	6.3	0.03	ND	ND	ND	ND	ND	17	ND	21	23	ND	ND	ND	4	7.1
SB1-5-50	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	14	7.4
SB1-6-60	ND	10	89	0.6	ND	ND	9.1	7.1	ND	ND	5.3	ND	ND	ND	17	ND	35	41	ND	ND	ND	13	7.6
SB1-7-69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	7.7
SB1-8-79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	7.8
SB1-9-89.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	7.9
SB1-10-99.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	7.9
SB9-1-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	6.8
SB9-2-20	ND	ND	87	ND	ND	ND	5.3	9.6	0.03	ND	4.2	ND	ND	ND	25	12	30	45	ND	-	-	7	7.3
SB9-3-29.5	ND	ND	120	0.5	ND	5.3	14	14	0.02	ND	7.4	ND	ND	ND	29	23	48	58	1.06	ND	ND	8	7.0
SB9-4-45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	7.3
SB9-6-60	ND	ND	120	0.7	ND	6.4	14	25	0.02	ND	9.5	ND	ND	ND	37	30	66	76	ND	ND	1.6	8	7.1
SB9-7-70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	6.9
SB9-8-80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	6.8
SB9-9-90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	7.1
SB9-10-100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	7.0
SB12-1-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	7.3
SB12-2-20	ND	ND	74	ND	ND	ND	7.0	7.8	0.10	ND	ND	ND	ND	ND	33	ND	31	34	ND	-	-	7	7.1
SB12-3-30	ND	12	99	0.6	ND	ND	10	12	0.08	ND	6.3	ND	ND	ND	23	ND	48	53	ND	ND	1.0	13	7.2
SB12-4-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	7.3
SB12-4-40 DUP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SB12-5-50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	6.8
SB12-6-60	ND	ND	82	ND	ND	ND	14	5.0	0.04	ND	ND	ND	ND	ND	23	ND	77	36	ND	ND	ND	8	7.2
SB12-7-70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	7.6
SB12-8-80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	6.9
SB12-9-87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	7.3
SB19-1-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	8.0
SB19-1-10 DUP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	8.1

TABLE 1-14

SUMMARY OF INORGANIC CHEMICAL ANALYSES PERFORMED ON SOIL SAMPLES
(October 1992)

Sample	Metals																					
	Ag	As	Ba	Be	Cd	Co	Cr	Cu	Hg	Mo	Ni	Pb	Sb	Se	Sr	Tl	V	Zn	CN	N	NO_3	Percentage Moisture(1)	Lab pH
SB19-2-18	ND	ND	95	ND	ND	ND	5.6	5.1	ND	ND	ND	ND	ND	ND	39	ND	30	29	ND	-	-	3	7.1
SB19-2-18 DUP	ND	ND	76	ND	ND	ND	3.1	4.3	ND	ND	ND	ND	ND	ND	16	ND	24	35	ND	-	-	3	6.9
SB19-3-30	ND	ND	40	ND	ND	ND	7.1	7.7	0.06	ND	ND	ND	ND	ND	31	ND	24	22	ND	ND	1.1	9	7.7
SB19-4-38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	7.6
SB19-5-50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	7.6
SB19-6-60	ND	ND	63	ND	ND	ND	5.1	11	0.10	ND	ND	ND	ND	ND	30	ND	36	38	ND	ND	ND	12	7.7
SB19-7-70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	7.5
SB19-8-80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	7.6
SB19-9-90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	7.8
SB21-1-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	7.2
SB21-2-20	ND	ND	55	ND	ND	ND	6.4	6.2	0.04	ND	ND	ND	ND	ND	20	ND	31	27	ND	-	-	3	7.1
SB21-3-30	ND	10	70	0.5	ND	ND	12	16	0.08	ND	5.6	ND	ND	ND	32	ND	53	43	-	ND	ND	10	7.4
SB21-4-60	ND	ND	51	ND	ND	ND	10	8.3	ND	ND	ND	ND	ND	ND	13	ND	34	26	ND	ND	ND	13	7.6
SB21-5-75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	7.6
SB21-6-80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20	7.7
SB21-7-90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	7.7
SB21-8-100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	7.1

Notes:

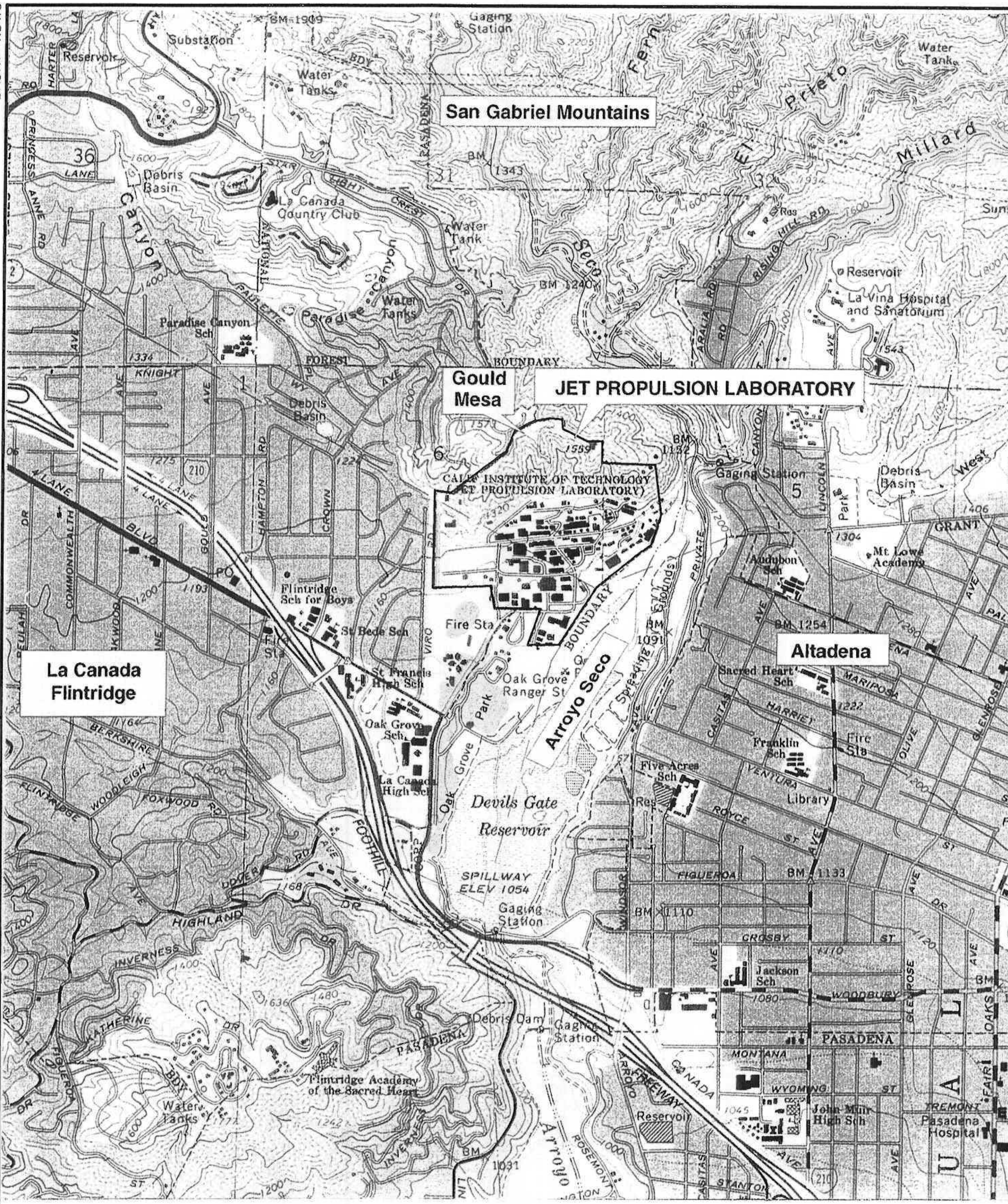
Values are reported in milligrams per kilogram (mg/kg) unless stated otherwise.

(1) Percent moisture as determined from total solids per unit volume.

ND - Not detected.

\- Not analyzed.

Reference: Ebasco, 1993a.



0 .5 mile

Source: USGS 7.5 Minute Topographic Quadrangle, 1966, Revised 1994

N

FIGURE 1–1

SITE LOCATION MAP
JET PROPULSION LABORATORY

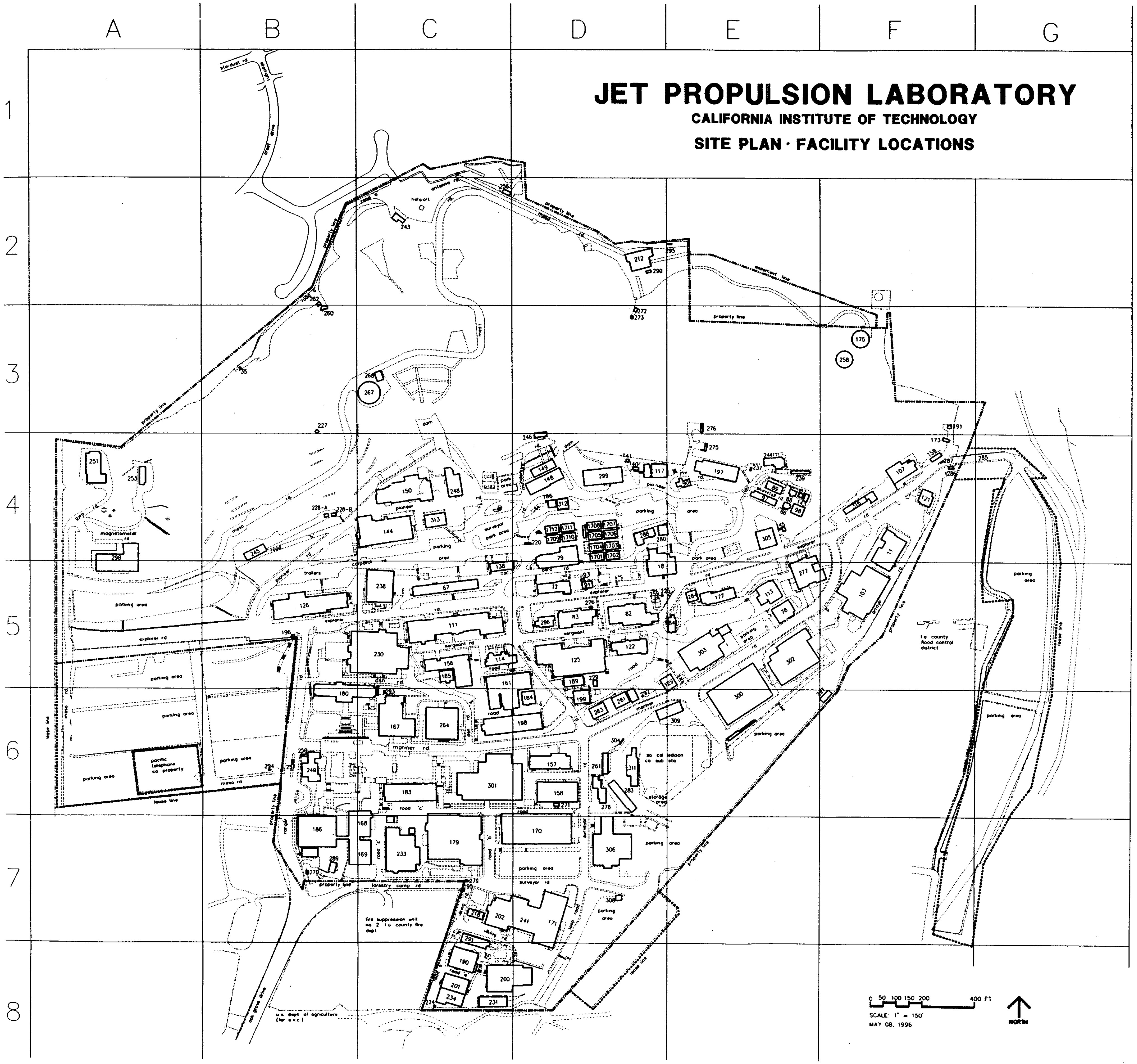
Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

SITE PLAN · FACILITY LOCATIONS



Facility Locations

No.	Facility Title	Location	No.	Facility Title	Location
11	Space Sciences Laboratory	4–F	227	Pistol Range Storage	3–B
18	Structural Test Laboratory	5–D	228	Cooling Tower (A–B)	4–B
35	Radio/Repeater Complex	3–B	229	Shielded Room Building	5–D
67	Material Research	5–C	230	Space Flight Operation Facility	5–C
72	Engineering Offices	5–D	231	Paint Shop	8–C
78	Hydraulics Laboratory	5–E	233	System Development	7–C
79	Wind Tunnel (20 inch)	4–D	234	Lumber Storage	8–C
82	High Vacuum Laboratory	5–D	237	Cooling Tower	4–E
83	Quality Assurance	5–D	238	Telecommunications	5–C
84	Chemical Materials Laboratory	5–E	239	Propellant Conditioning Laboratory	4–E
86	Solid Oxidizer Laboratory	4–E	241	Receiving and Shipping	7–D
87	Propellant Conditioning Laboratory	4–E	243	Remote Antenna Range Control	2–C
88	Mixing Laboratory	4–E	244	Chemical Engineering	4–E
89	Laser Laboratory	4–E	245	Spectroscopy Laboratory	4–B
90	Pyrotechnics Laboratory	4–E	246	Soils Test Laboratory	4–D
91	Air Dryer	5–D	248	10–Foot Space Simulator	4–C
93	Vaporizer	5–D	249	Visitor Reception	6–B
97	Development Laboratory and Offices	4–E	250	Main Guard Shelter	6–B
98	Solid Fuel Laboratory	4–E	251	Gyro Laboratory	4–A
103	Fabrication Shop	5–F	252	Guard Shelter	6–B
107	Laser Research Laboratory	4–F	253	Magnetic Laboratory	4–A
111	Technical Information	5–C	256	Model Range Control	2–C
113	Pneumatics Laboratory	5–E	257	Main Guard Island	6–B
114	Electronics Development	5–C	258	Water Reservoir	3–F
117	Liquid and Solid Propellant Laboratory	4–D	259	Liquid Nitrogen Bottling Storage	5–D
121	Analytical Instruments Laboratory	4–F	260	Illuminator Equipment	3–B
122	Energy Conservation Systems	5–D	261	Controlled Storage	6–D
125	Combined Engineering Support	5–D	262	Radiometer	2–B
126	Information Systems Development	5–B	263	First Aid	6–D
129	Combustion Research Laboratory	5–E	264	Space Flight Support	6–C
138	Mission Operations	5–C	267	Water Reservoir	3–C
140	Propulsion Materials Storage	4–D	268	Pump House	3–C
141	Propulsion Materials Storage	4–D	270	Sewage Metering Station	7–B
143	Solid Rocket Dock	4–E	271	Oil Storage	6–D
144	Environmental Laboratory	4–C	272	East Illuminator	3–D
145	Magazine – Propellant	4–E	273	Antenna Tower	3–D
148	Energy Conservation Laboratory	4–D	275	Pyrotechnic Storage	4–E
149	Energy Conservation Development	4–D	276	Propellant Storage	3–E
150	25–Foot Space Simulator	4–C	277	Isotope Thermoelec. Sys. Appl. Lab.	5–E
156	Computer Program Offices	5–C	278	Robotics Laboratory	6–D
157	Applied Mechanics	6–D	279	Guard Island	7–C
158	Material Research Processing Laboratory	6–D	280	Static Test Tower	4–D
159	Pump House (water)	4–F	281	Fire and Guard Headquarters	6–D
161	Telecommunications Laboratory	5–C	283	Metal Storage	6–D
166	Cooling Tower	4–D	284	Transportation Office	5–E
167	Cafeteria	6–C	285	Arroyo Bridge	4–G
168	Instrument System Laboratory	7–C	286	Guard Shelter	4–F
169	Earth Space Science	7–C	287	Guard Island	4–F
170	Fabrication Shop	7–D	288	Project Equipment Storage	4–D
171	Material Services	7–D	289	Main Sewage Lift Station	7–B
173	Test Shelter	4–F	290	Antenna Inspection	2–D
175	Water Reservoir	3–F	291	Procurement Services	8–C
177	Transportation Garage	5–E	292	Fire Station	6–D
179	Spacecraft Assembly Facility	7–C	293	Instrumentation Cable Amplifier Building	6–C
180	Administration	6–B	294	Guard Shelter (Visitor Lot)	6–B
183	Physical Science Laboratory	6–C	295	Antenna Test Facility	2–E
184	Electronic Stores	6–D	296	Central Cooling Tower Water System	5–D
185	Programming Office	5–C	297	Xenon Test Laboratory	6–F
186	Science Exhibits and Engineering	7–B	298	Frequency Standard Laboratory	4–A
189	Electronics Laboratory Annex	5–D	299	Assembly Handling & Shpg Equip Fac.	4–D
190	Procurement Offices	8–C	300	Earth and Space Science Laboratory	6–E
191	Materials Compatability Laboratory	3–F	301	Central Engineering Building	6–C
195	Guard Shelter	7–C	302	Microdevices Laboratory	5–E
196	Guard Shelter	5–B	303	Engineering Support Building	5–E
197	Solid Propellant Engineering Laboratory	4–E	304	Disintegrator	6–D
198	Control Systems Laboratory	6–D	305	Hazardous Waste/Cryogenic Storage Facility	4–E
199	Celestial Simulator	6–D	306	Observational Instruments Laboratory	7–D
200	Facilities Engineering and Services	8–C	308	Sewage Lift Station	7–D
201	Carpenter Shop	8–C	309	Maintenance Storage Facility	6–D
202	Procurement and Communications Support	7–C	311	Ground Maintenance Facility	6–D
212	Antenna Laboratory	2–D	312	Shelter Maintenance Facility	4–D
218	Credit Union	7–C	313	Mirror Refurbishment	4–C
220	ICS Terminal	4–D	316	Hazmat Storage and Dist Facility	4–F
224	Sewage Lift Station	8–C			
225	Nitrogen Facility Office	5–D	MODULARS:		
226	Solvent Storage	5–D	1701–1712	Modular Offices	4–D

FIGURE 1–2

SITE FACILITY MAP
JET PROPULSION LABORATORY

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

BRDR1-3.DWG

Explanation

Boring 1

Boring Location and total depth drilled

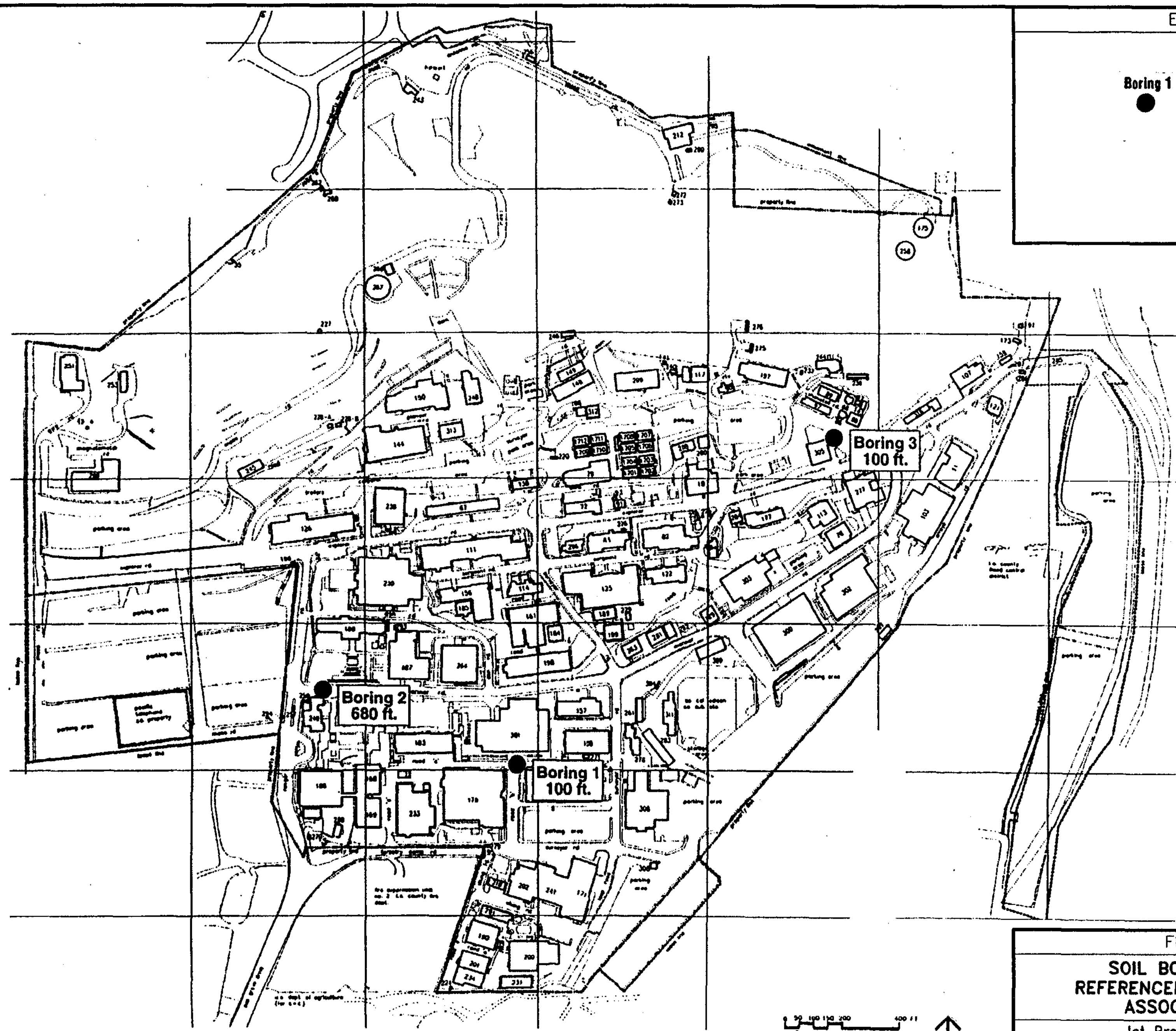


FIGURE 1-3

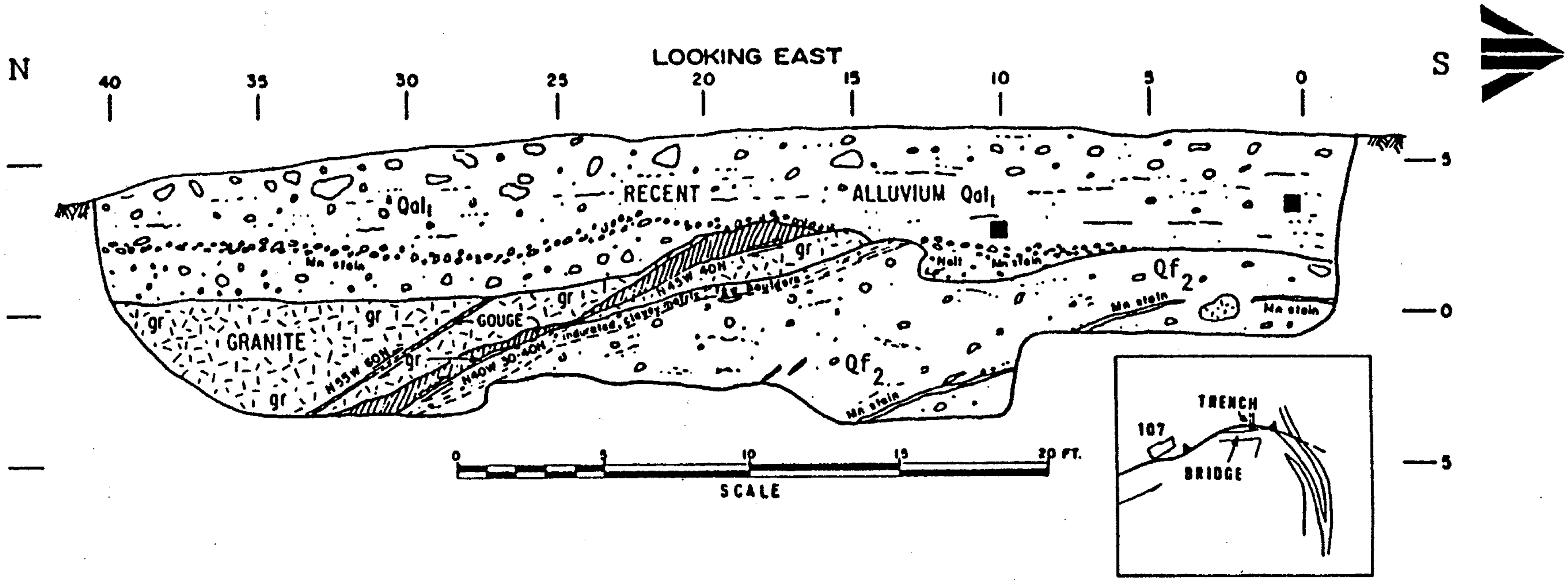
SOIL BORING LOCATIONS REFERENCED IN CRANDALL AND ASSOCIATES (1977a)

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

2-4-99

BRDR1-4.DWG



SECTION VIEW: BACKHOLE TRENCH CUT IN ARROYO SECO, NORTH OF JPL BRIDGE; BEARING N3°E; WIDTH, 30 IN.

Qal_1: Gray brown, crudely bedded (flat) pebble-to-boulder conglomerate. Boulders to 3 ft. Contains a distinct ~6-in. boulder bed, the bottom discolored by manganese stains. Two carbon samples (■) collected. Clasts include Lowe Granodiorite, Wilson Diorite, and a dark augen gneiss with porphyroblasts. Boulders are fresh. Large rusty nail found in scoured area at Station 12.

Qf_2: Brown to yellow-brown pebble to boulder fanglomerate. Boulders to 3 ft. Bottom of trench determined by refusal on large boulders. Moderately indurated. Wilson Diorite boulders highly weathered. Lowe Granodiorite fresh. Gneiss fresh. Contains another manganese stain layer. Bedding indistinct to crude, variable shallow dips. Some diorite clasts appear smeared out. Attitudes of striations in dirt above dislodged boulder at Station 12 are N45E, 20°. A ±12-in. well-indurated layer with clayey matrix just below granite contact. Stretched boulders are subparallel to faults.

Gouge: Light green, brown, white, and gray clay. Banded in places. Contains some granite pebbles. Upper thin gouge zone is bisected by a plane containing abundant roots.

Granite: Pink to light green, fine-grained granite to quartz monzonite. Highly sheared and decomposed.

FIGURE 1-4

CROSS SECTION OF CALTECH TRENCH ACROSS JPL THRUST FAULT (AGBABIAN 1977)

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

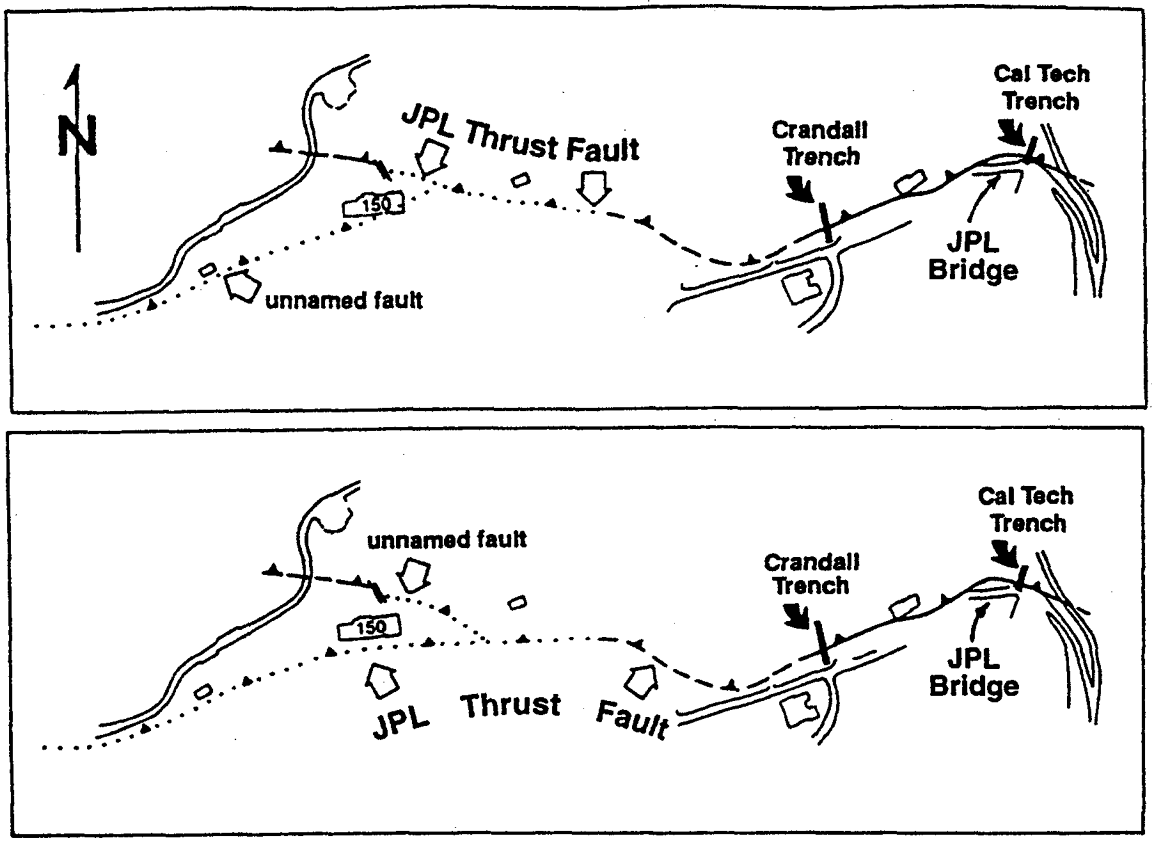
2-4-99

Explanation

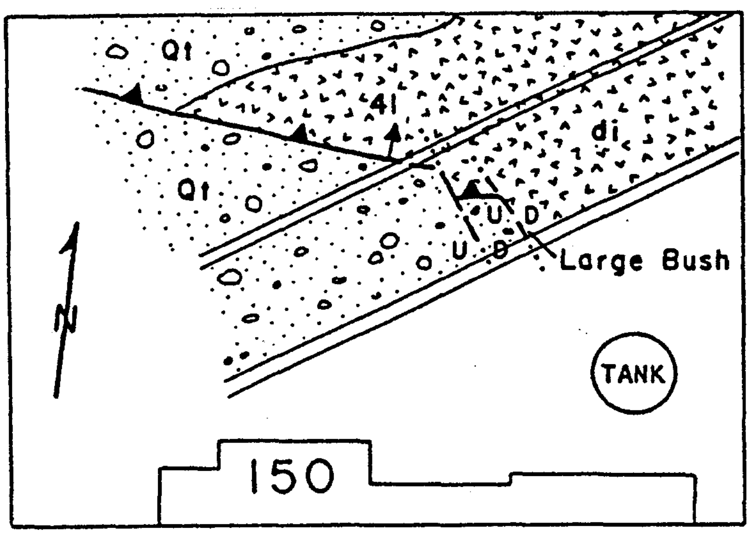
di : diorite

Qt : Quaternary Terrace deposit

41 : Degrees of Fault Inclination



Alternative Interpretations of JPL Fault from Agbabian Associates, 1977.



Geologic Interpretations of Fault Pattern Exposed Behind Building #150; Agbabian Associates, 1977.

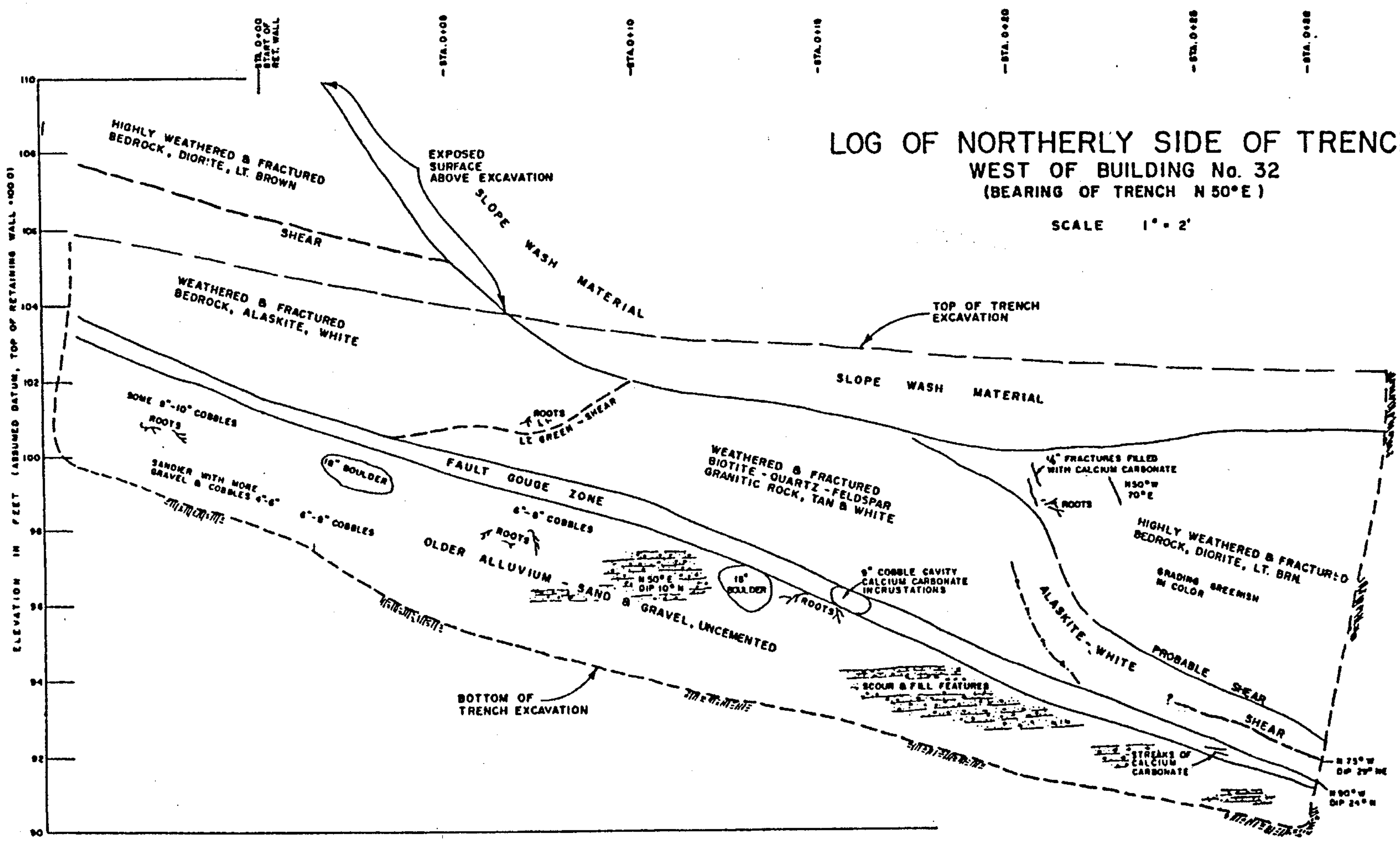
FIGURE 1–5

JPL THRUST FAULT AS MAPPED BY AGBABIAN ASSOCIATES, (1977)

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

BRDR1-6.DWG



Source: Agbabian Associates, 1977

FIGURE 1–6

CROSS SECTION OF TRENCH ACROSS JPL THRUST FAULT

Jet Propulsion Laboratory
Pasadena, California

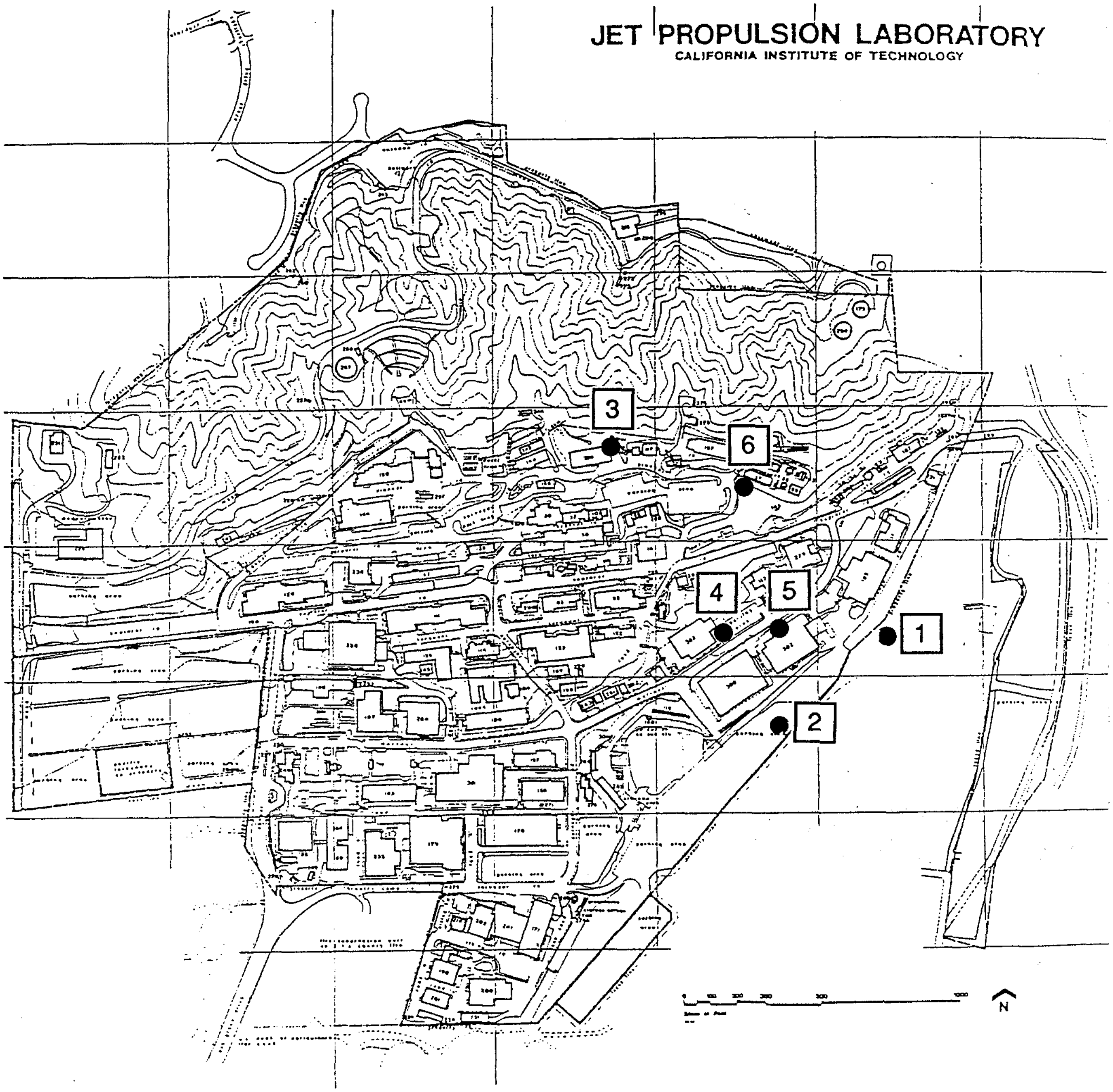
FOSTER WHEELER ENVIRONMENTAL CORPORATION

2-4-99

BRDR1-8.DWG

Explanation

● **Suspected Seepage Pits used for Waste Disposal** ***(approximate Locations)***



Reference: EBASCO 1988a and 1988b

FIGURE 1–8

SUSPECTED SEEPAGE PIT LOCATIONS AS IDENTIFIED IN THE PRELIMINARY ASSESSMENT AND SITE INSPECTION REPORTS

Jet Propulsion Laboratory
Pasadena, California

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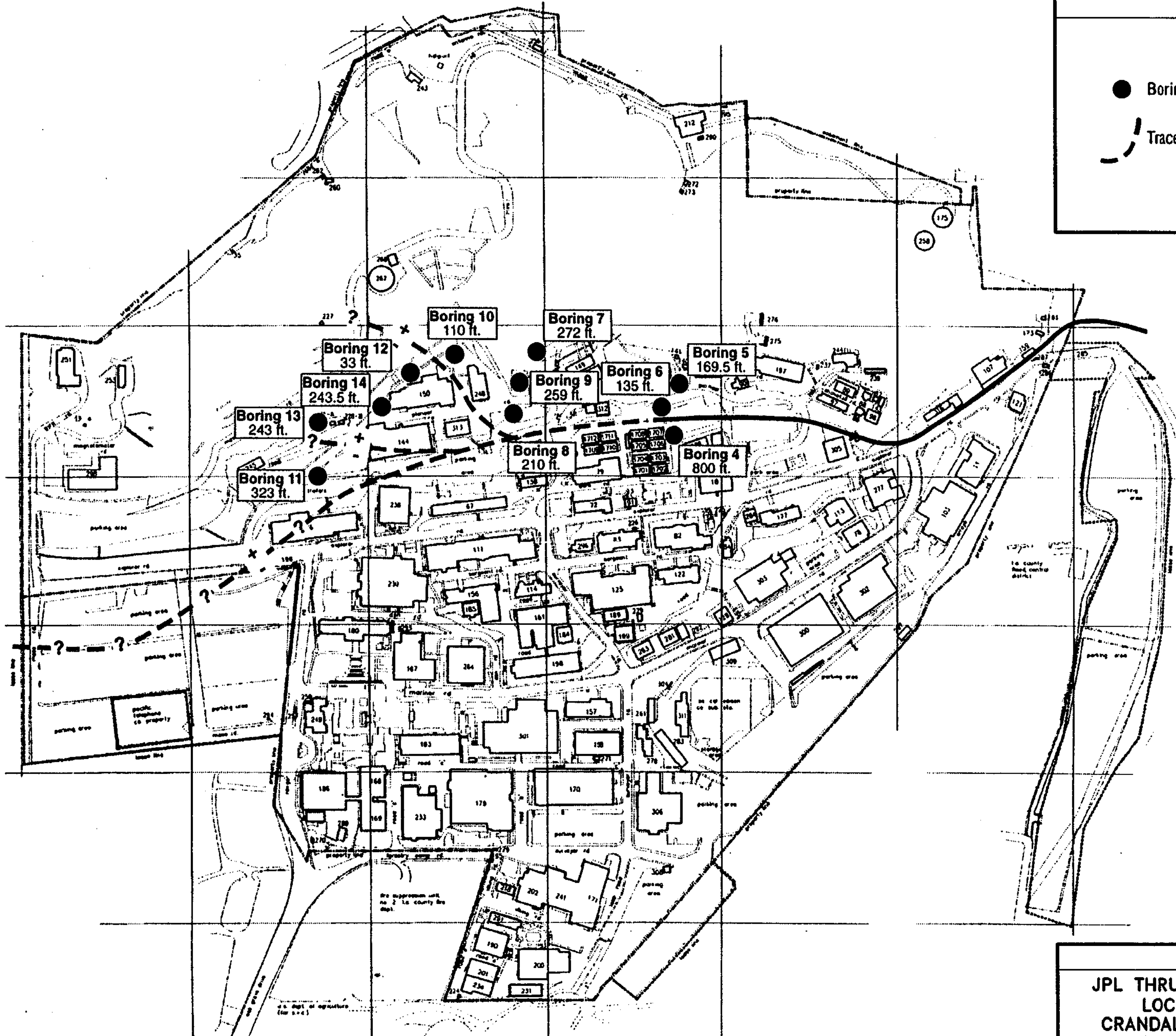
2-4-99

BRDR1-7.DWG



Explanation

● Boring Location and Total Depth Drilled

Trace of JPL Thrust Fault (Crandall, 1977b)

FIGURE 1-7

JPL THRUST FAULT AND SOIL BORING LOCATIONS REFERENCED IN CRANDALL AND ASSOCIATES, 1977b

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Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

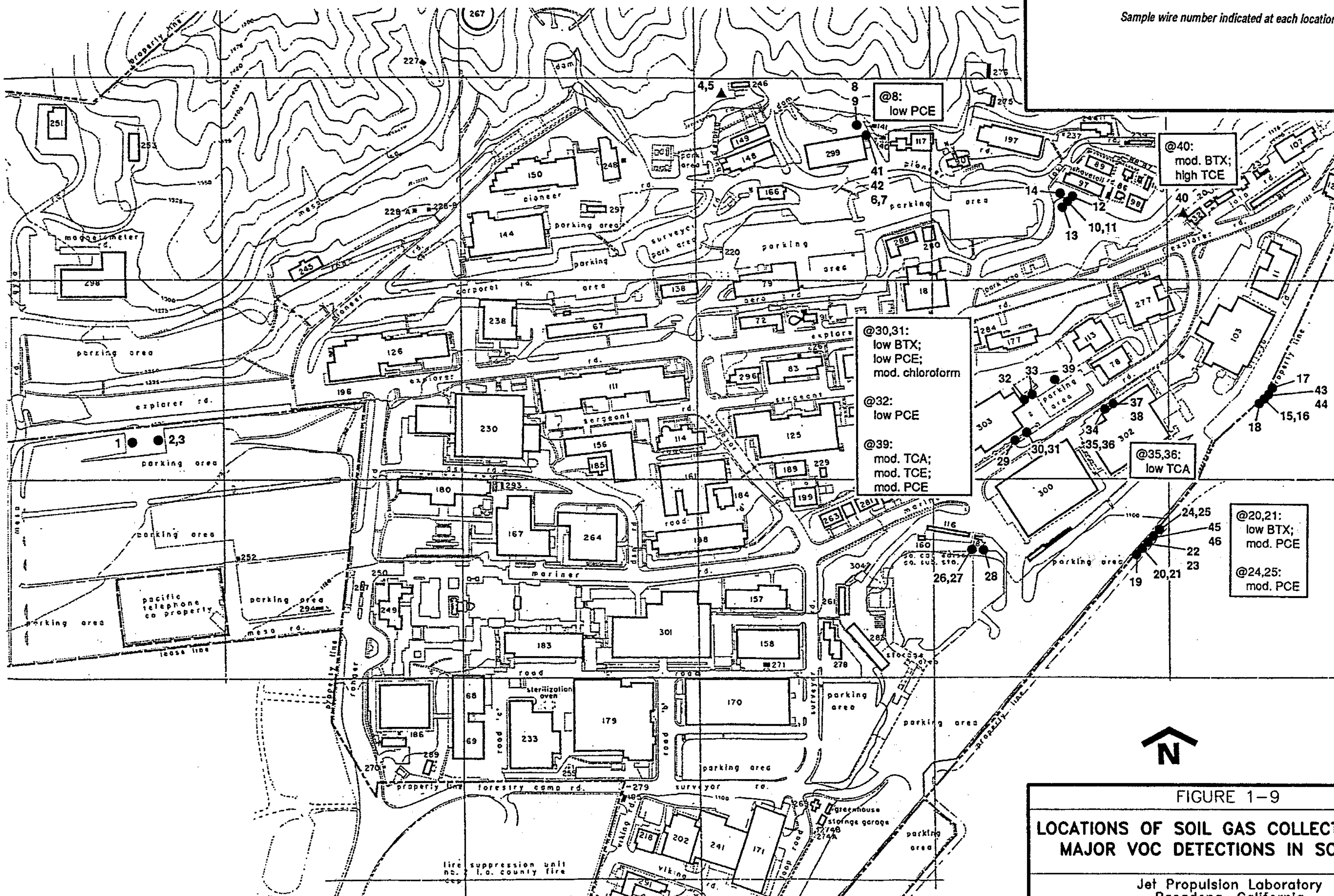
2-4-99

BRDR1-9.DWG

Explanation

- ● Soil Gas Collector Location
- ▲ Background Soil Gas Collector Location

Sample wire number indicated at each location



Reference: EBASCO, 1990a

FIGURE 1-9

LOCATIONS OF SOIL GAS COLLECTORS AND MAJOR VOC DETECTIONS IN SOIL GAS

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

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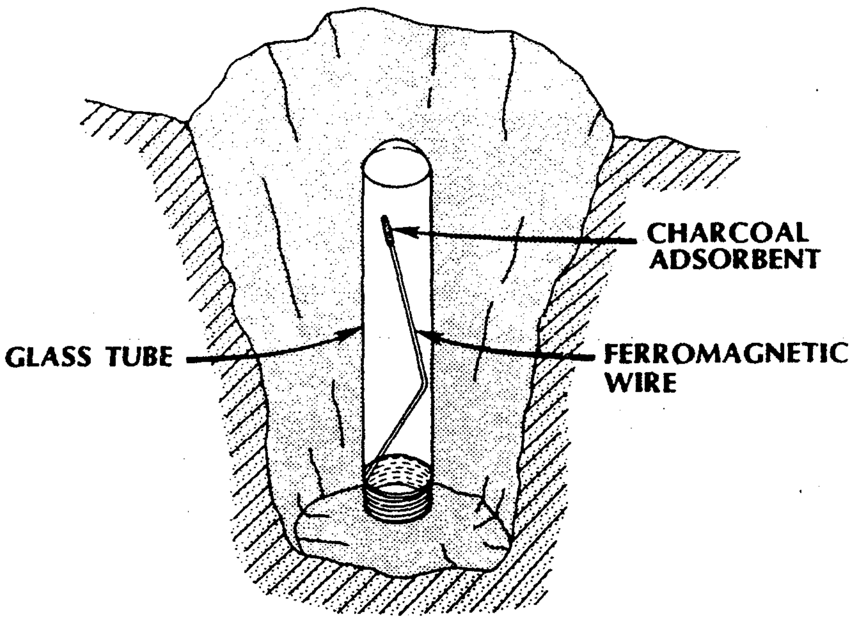
BRDR1-10.DWG



ISOMETRIC VIEW

Reference: EBASCO, 1990a

FIGURE 1–10

SCHEMATIC DIAGRAM OF SOIL GAS COLLECTOR

Jet Propulsion Laboratory
Pasadena, California

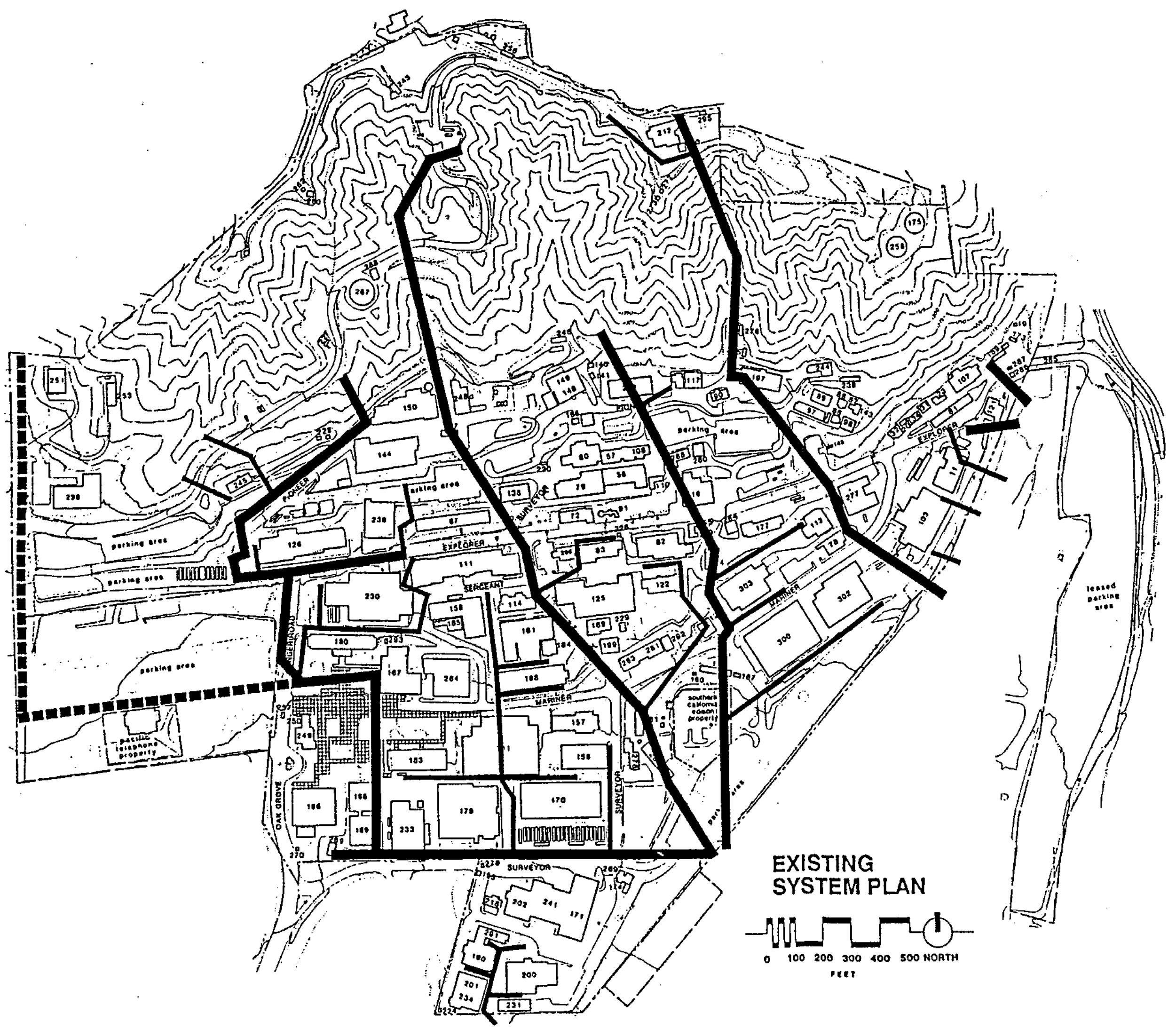
FOSTER WHEELER ENVIRONMENTAL CORPORATION

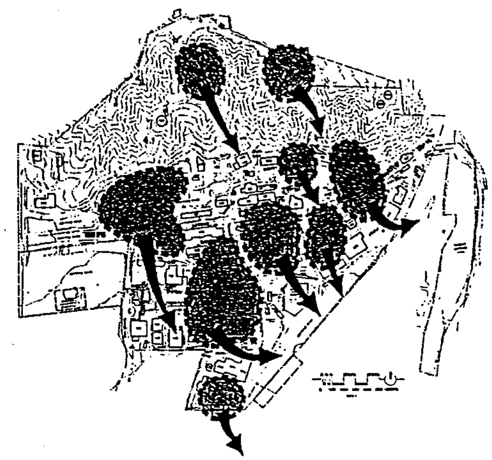
2-4-99

BRDR1-11.DWG

Explanation

12" TO 24" COLLECTOR LINES
24" TO 48" TRUNK LINES
OPEN CHANNEL





EXISTING
SYSTEM SCHEMATIC
LEGEND
TRIBUTARY AREA
FLOW COMPONENT

N

FIGURE 1-11

STORM DRAINAGE SYSTEM AT JET PROPULSION LABORATORY

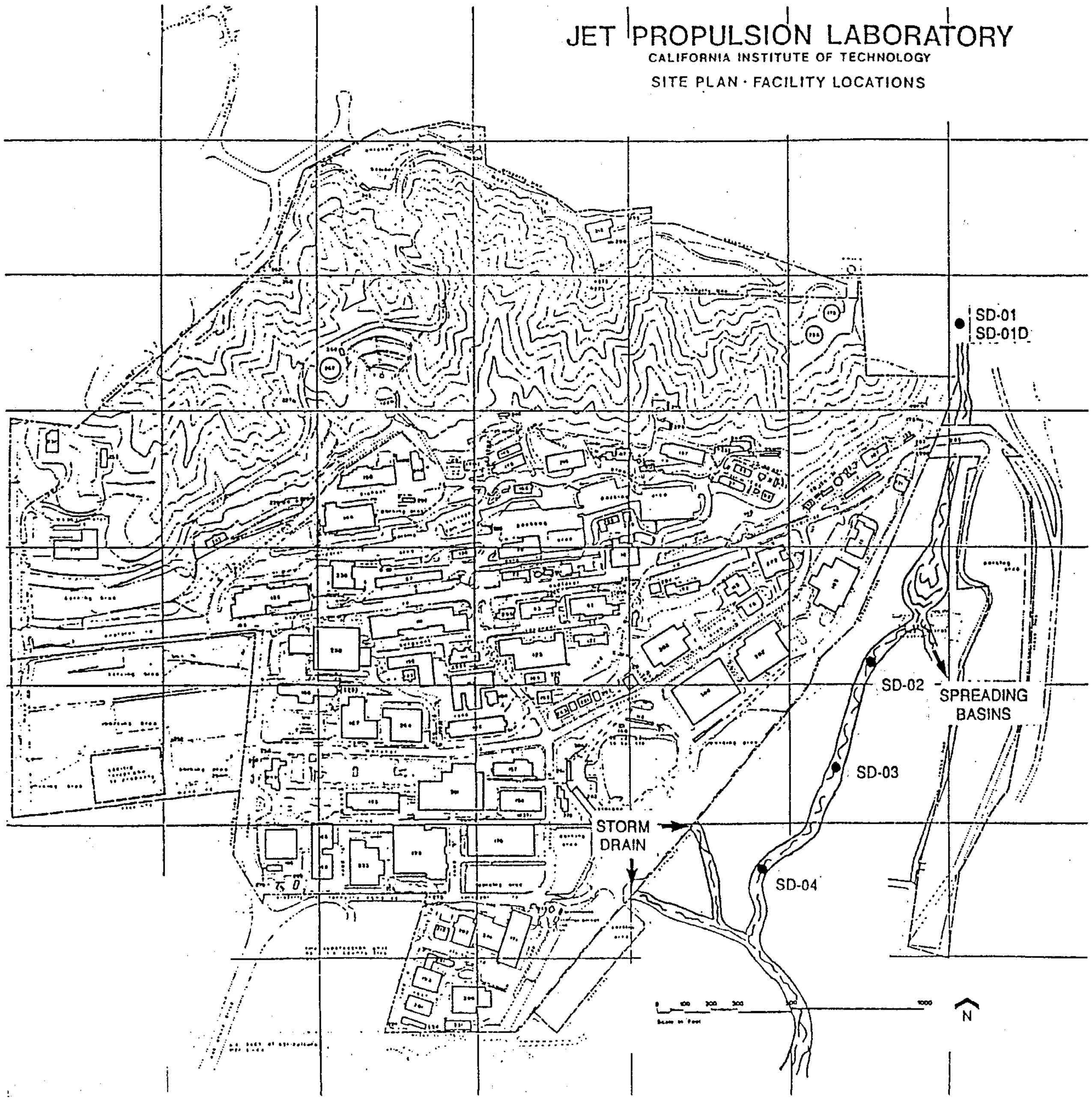
Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

From: Supplemental Information to the Expanded Site Inspection Report Dated November 1990

Source: Adapted from Boyle Engineering, 1988

2-4-99



Reference: EBASCO, 1990b

Explanation

● SD-01 SEDIMENT SAMPLE LOCATION

FIGURE 1–12

SURFACE SEDIMENT SAMPLE LOCATIONS COMPLETED AS PART OF THE HRS

Jet Propulsion Laboratory
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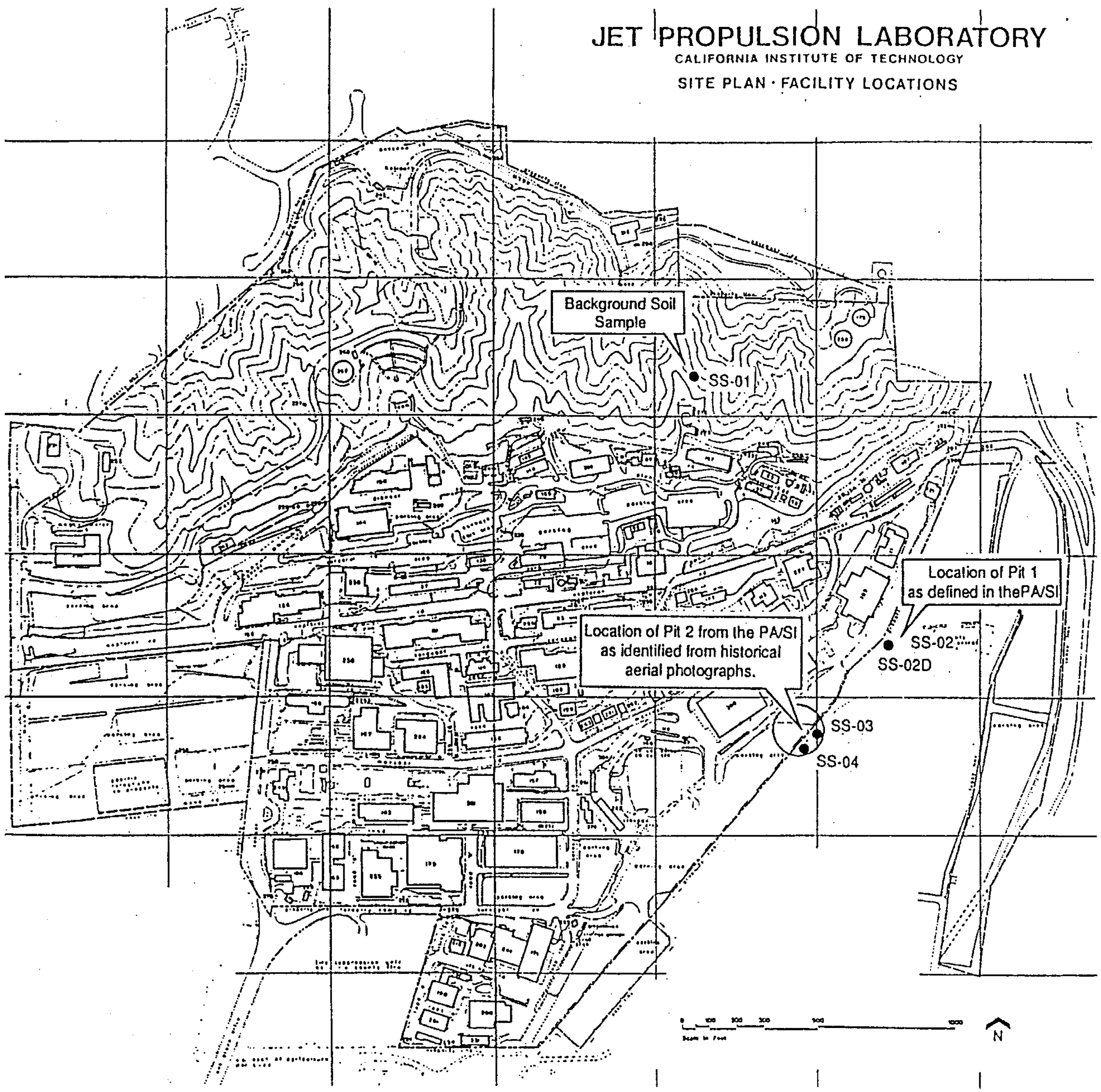
BRDR1-13.DWG



Reference: EBASCO, 1990b

Explanation

● SD-01 SOIL SAMPLE LOCATION

FIGURE 1–13

SOIL SAMPLE LOCATIONS COMPLETED AS PART OF THE HRS

Jet Propulsion Laboratory
Pasadena, California

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2-4-99

Explanation

12 ● Seepage Pit or Dry Well Location and Number *(approximate Locations)*

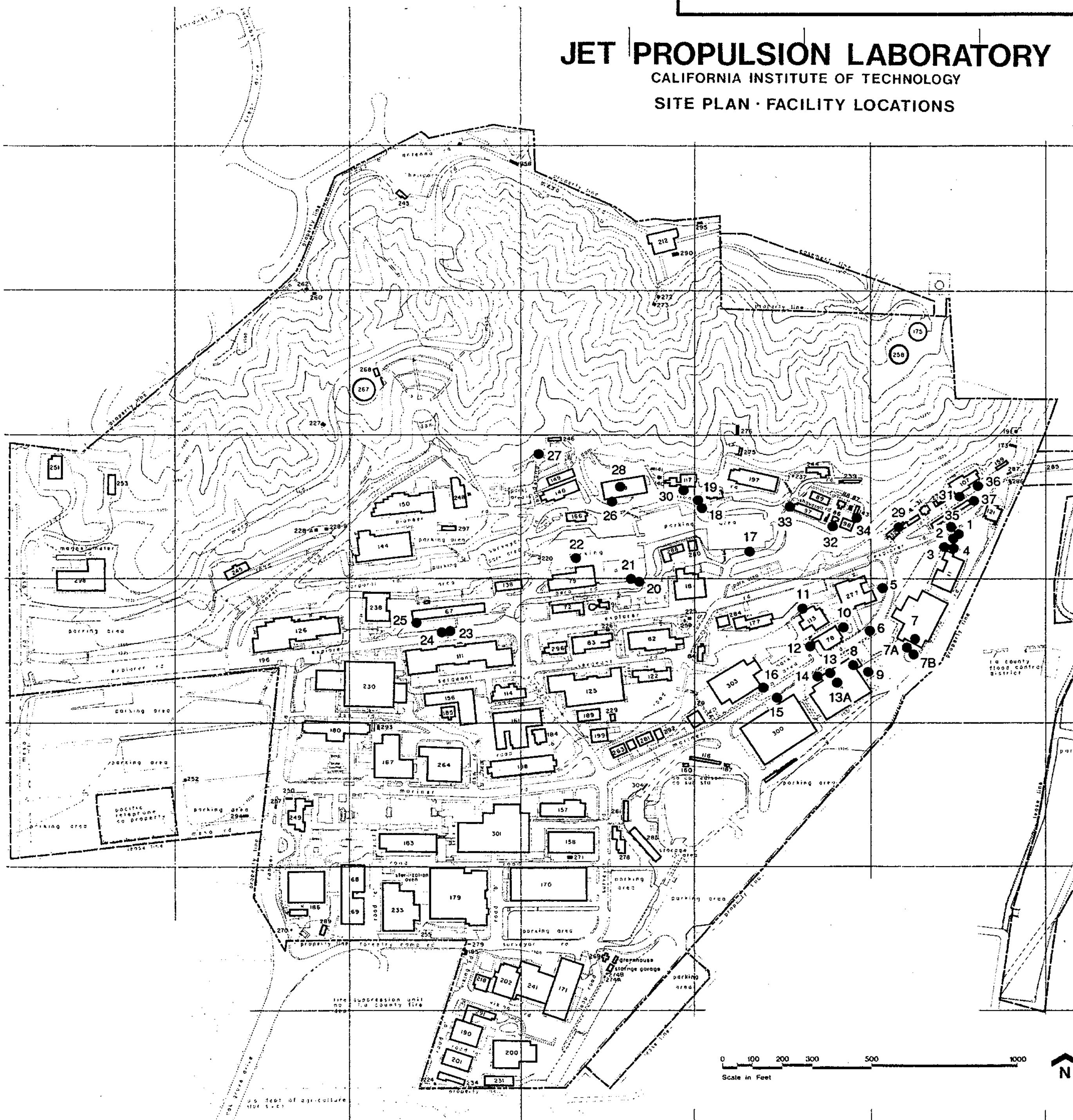

FIGURE 1–14

LOCATIONS OF KNOWN SEEPAGE PITS AND DRY WELLS

Jet Propulsion Laboratory
Pasadena, California

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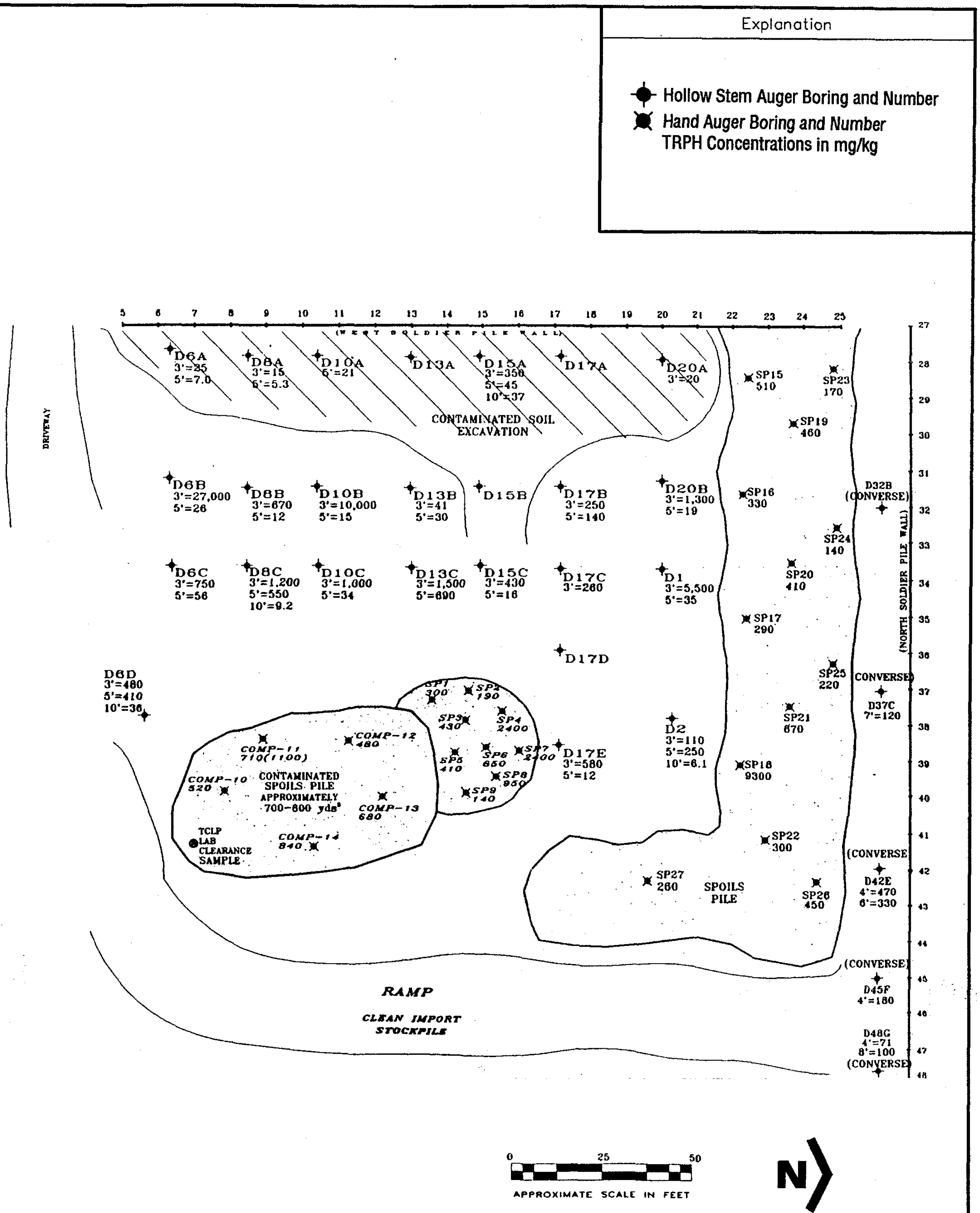
BRDR1-15.DWG



Reference: Maness, 1992

FIGURE 1-15

BORING AND SAMPLING LOCATIONS IN BUILDING 306 EXCAVATION

Jet Propulsion Laboratory
Pasadena, California

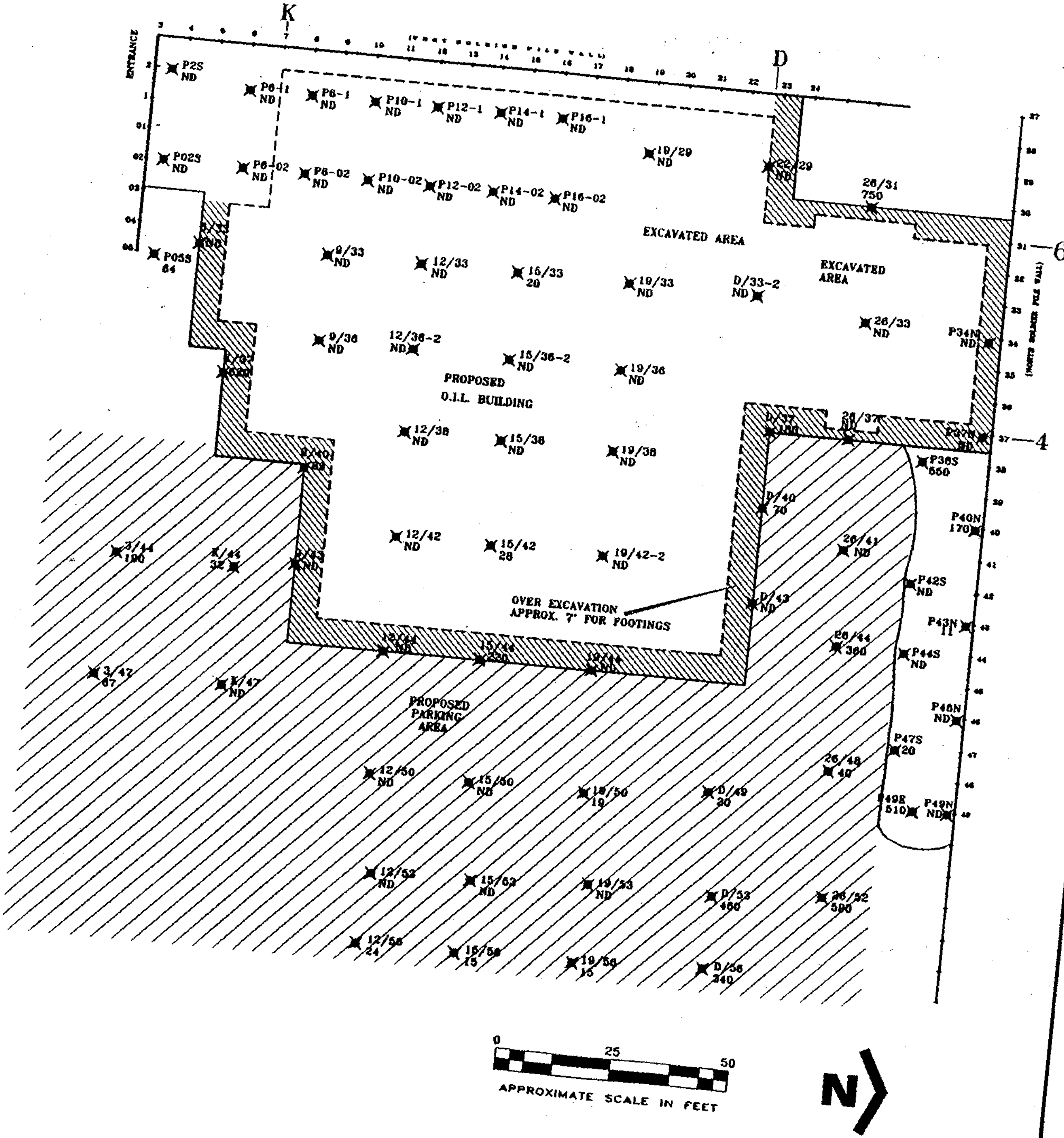
FOSTER WHEELER ENVIRONMENTAL CORPORATION

2-4-99

BRDR1-16.D

Explanation

Sample Location and Number
TRPH Concentrations in mg/kg



2-4-99

FIGURE 1-16

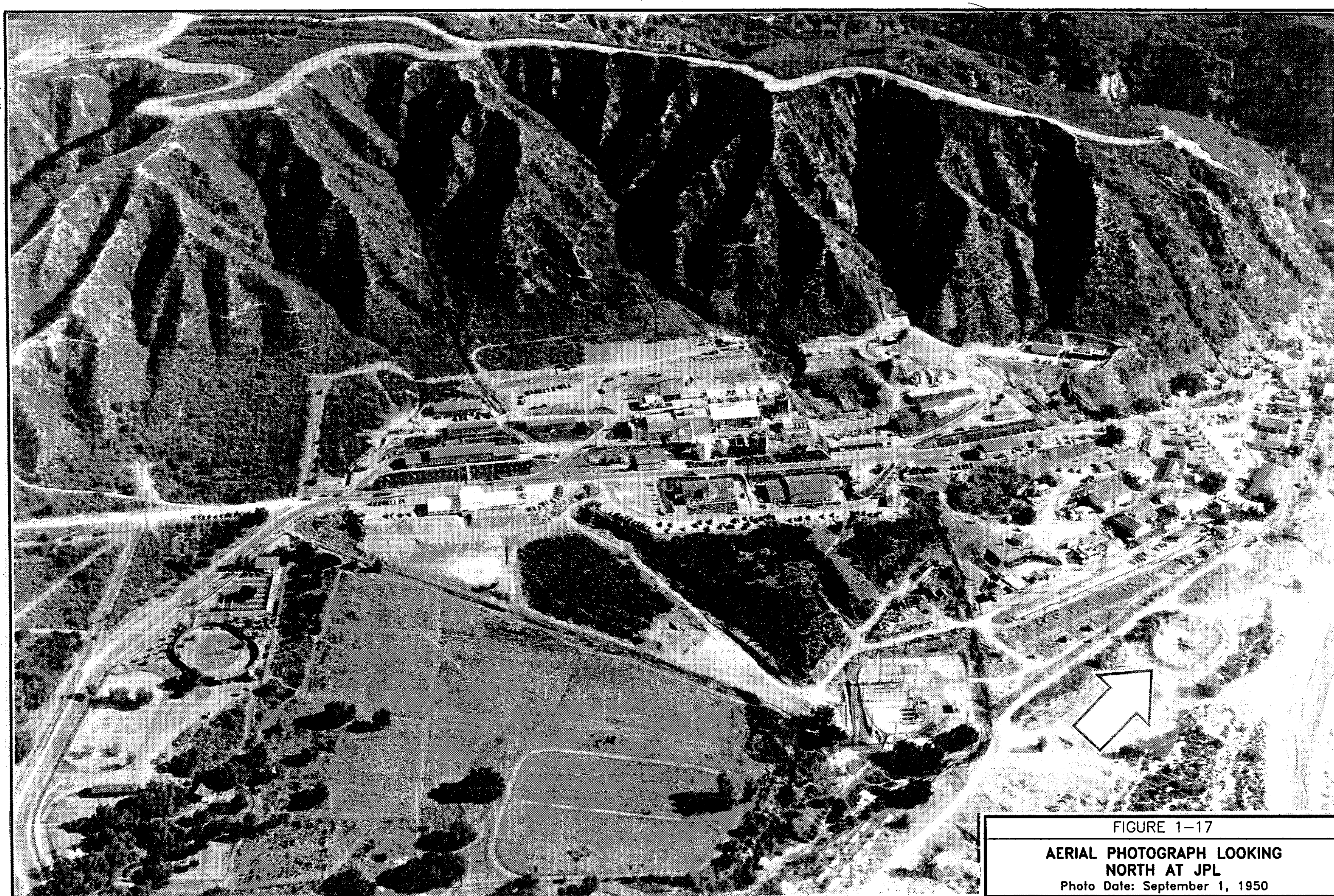
CONFIRMATION SAMPLING LOCATIONS AND RESULTS

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

Reference: Maness, 1992

BRDR1-17.DWG



Notice large waste disposal pit in the right hand corner of photo; identified as Pit 2 in PA and SI reports. (Aerial Photo No. JP 931C from JPL Photo Library)

FIGURE 1-17

AERIAL PHOTOGRAPH LOOKING NORTH AT JPL

Photo Date: September 1, 1950

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

2-11-99

BRDR1-18.DWG

Notice pit inside mortared-rubble wall at bottom of photo; identified as Pit 3 in PA and SI reports. (Aerial Photo No. JB 1110Z from JPL Photo Library)

FIGURE 1-18

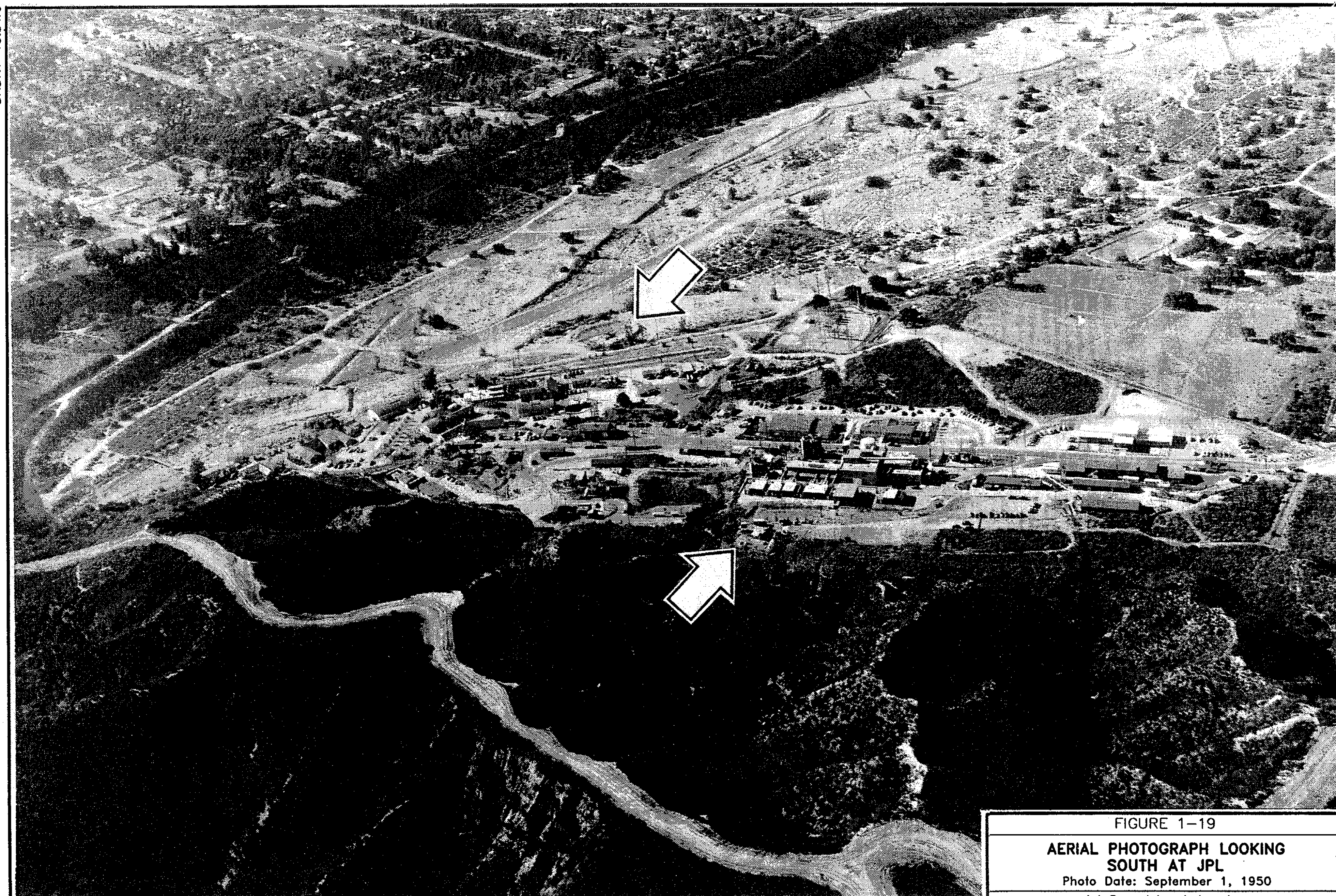
AERIAL PHOTOGRAPH LOOKING SOUTH AT PART OF JPL

Photo Date: Unknown

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

2-4-99



Notice Pit 2 from in the Arroyo and Pit 3 from the PA and SI reports along lower ledge of JPL. (Aerial Photo No. JP 931H from JPL Photo Library)

FIGURE 1-19

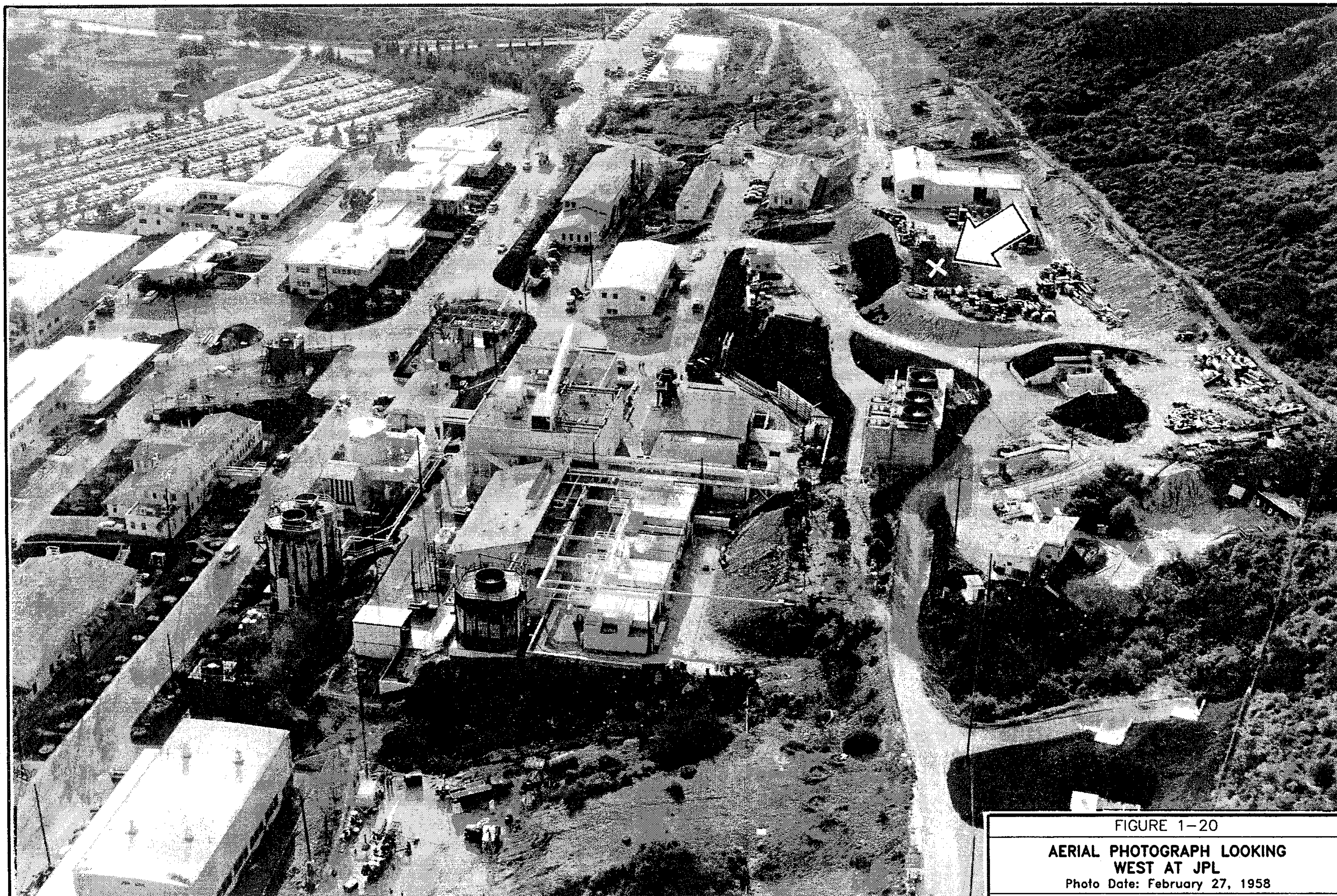
AERIAL PHOTOGRAPH LOOKING SOUTH AT JPL

Photo Date: September 1, 1950

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

BRDR1-20.DWG



Salvage Yard and Building 119 in upper right of photo. Dumping reportedly occurred in vicinity of the "X". (Aerial Photo No. JB 1673B from JPL Photo Library)

FIGURE 1-20

AERIAL PHOTOGRAPH LOOKING WEST AT JPL

Photo Date: February 27, 1958

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

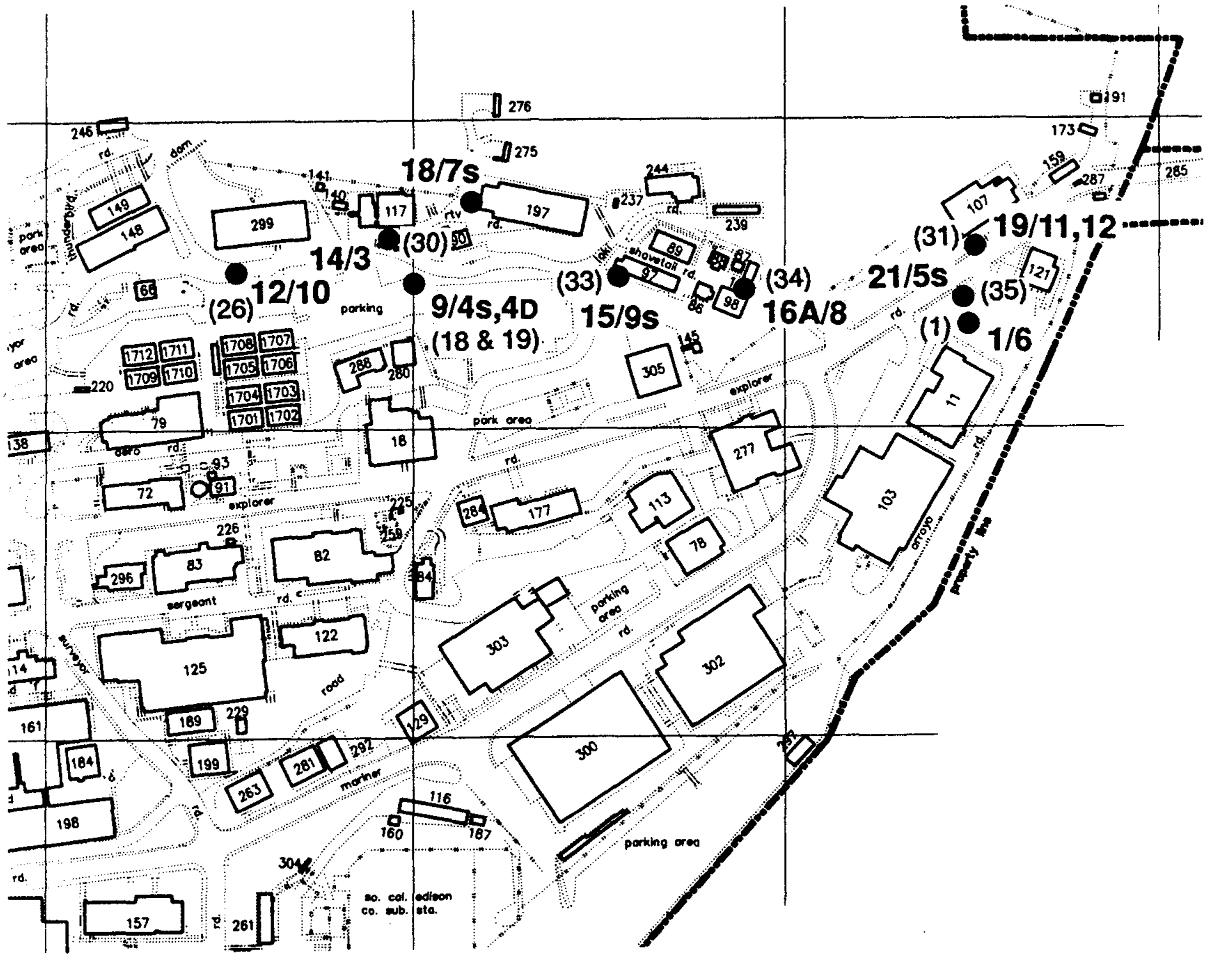
2-4-99

BRDR1-21.DWG

Explanation

● **1/6** - *Soil Boring Number/Soil Gas Sample Number*

(1) - *Seepage Pit Numbers*



N

Scale in feet

0 300

FIGURE 1–21

SOIL GAS SAMPLING LOCATIONS

Jet Propulsion Laboratory
Pasadena, California

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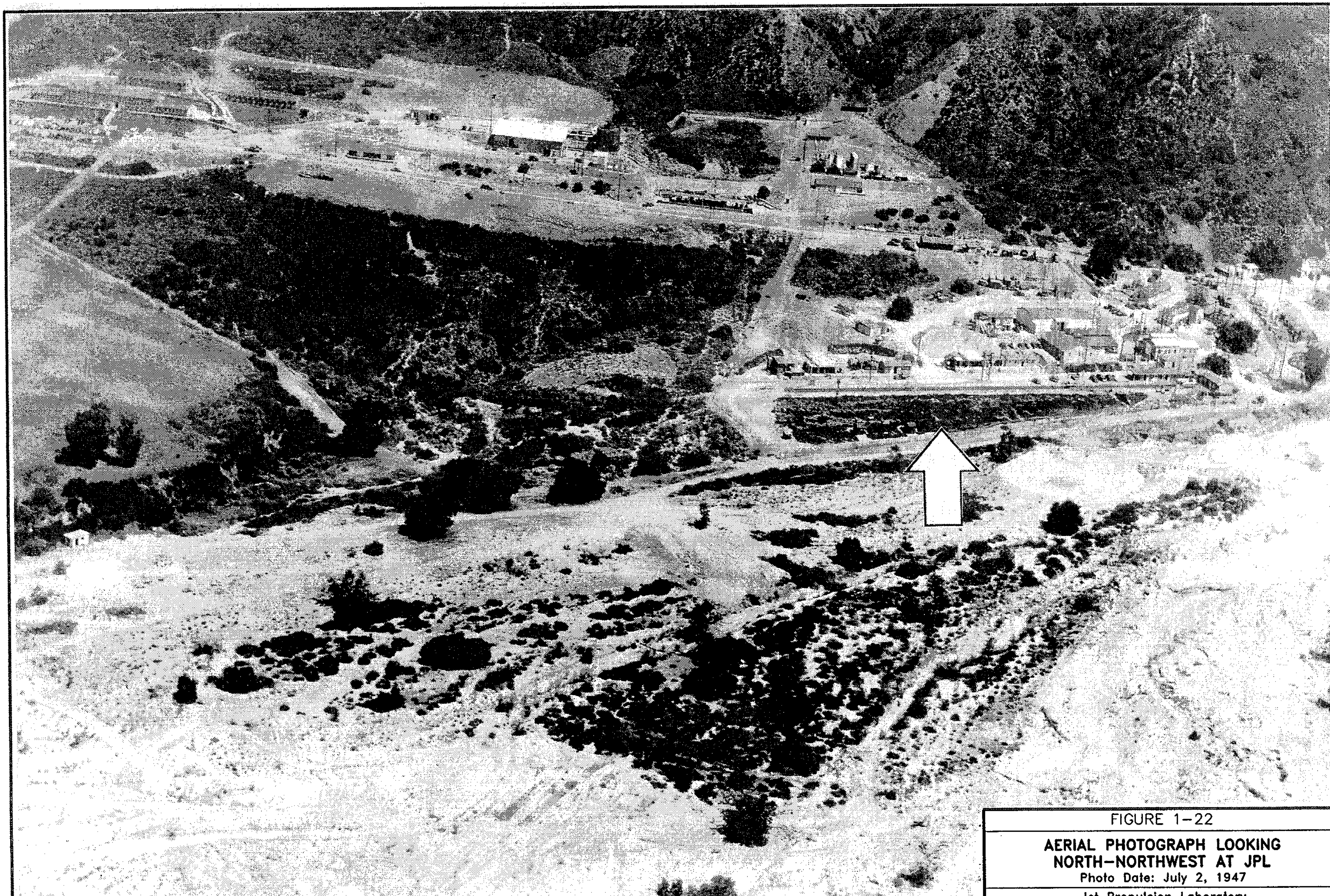
2-4-99



Vegetated slope parallel to Towing Channel at center-right.
(Aerial Photo No. JB 358G from JPL Photo Library)

FIGURE 1-22

AERIAL PHOTOGRAPH LOOKING NORTH-NORTHWEST AT JPL
Photo Date: July 2, 1947

Jet Propulsion Laboratory
Pasadena, California

FOSTER WHEELER ENVIRONMENTAL CORPORATION

BRDR1-22.DWG

2-4-99

2.0 PHYSICAL SETTING

The description of the physical setting of the study area is based on field observations, information from previous investigations and analytical data. The site features discussed in the following sections include both regional and local aspects of physiography, meteorology, geology and hydrogeology.

2.1 REGIONAL SETTING

2.1.1 Physiography/Topography

The JPL site is located within the San Gabriel Valley, in the eastern portion of Los Angeles County. The San Gabriel Valley forms a broad, southward-sloping plain that is bound on all sides by hills and mountains of much higher relief (Figure 2-1). The average slope of the valley floor is approximately 65 feet per mile.

The San Gabriel Valley is bound to the north by the San Gabriel Mountains, an east-west trending range of relatively steep, rocky ridges that rise from about 900 feet in elevation at their base, to more than 10,000 feet at the crest. To the south, southwest, and southeast, the valley is bound by a series of east-west trending hills that include the Repetto, Merced, Puente, and San Jose Hills. This system of relatively low hills rises approximately 500 feet from the valley floor to form a crescent shape, separating the southern edge of the San Gabriel Valley from the coastal plain of Los Angeles. A 1.5-mile break in these hills, located northwest of Whittier, is referred to as the Whittier Narrows.

Most of the rivers and tributaries that traverse the valley floor generally flow in a southerly direction. Almost the entire natural surface outflow from the San Gabriel Valley passes through the Whittier Narrows (Figure 2-1). The JPL facilities are located on the western margin of the Arroyo Seco, an ephemeral stream that flows southward, out of the San Gabriel Mountains.

2.1.2 Regional Meteorology

The San Gabriel Valley has a semi-arid Mediterranean climate characterized by mild, rainy winters and warm, dry summers. Rainfall in the area is variable though it typically averages approximately 15 inches per year overall (Boyle Engineering, 1988). The rainfall in the valley is greater than that in the City of Los Angeles as a result of orographic effects created by the nearby San Gabriel Mountains. The majority of the annual precipitation in the San Gabriel Valley, roughly 80 percent, occurs between the months of November and April.

Temperatures in the San Gabriel Valley are relatively mild, with August typically being the warmest month and January the coolest. Extremes for the area range from about 30°F in January to 105°F during the summer months.

Wind patterns change seasonally in both strength and direction in response to normal seasonal variations in barometric pressure systems. Generally, winds are mild throughout the year, characterized by ocean breezes (onshore) during the day and land breezes (offshore) at night.

Occasionally during the fall, the area is affected by the "Santa Ana" winds. These winds occur as the result of strong high-pressure systems moving into parts of Nevada and Utah creating strong, hot and dry winds originating from the northeast. Near the mouth of canyons oriented along the direction of airflow, these winds can be particularly strong.

2.1.3 Regional Geology

JPL is located immediately south of the southwestern edge of the San Gabriel Mountains (Figure 2-1). The San Gabriel Mountains, together with the San Bernardino Mountains to the east and the Santa Monica Mountains to the west, make up a major portion of the east-west trending Transverse Ranges province of California. This province is dominated by east-west trending folds, reverse faults, and thrust faults indicating a history dominated by north-south compressional deformation.

The San Gabriel Mountains are primarily composed of crystalline basement rocks. These rocks range in age from Precambrian to Tertiary and include various types of diorites, granites, monzonites, and granodiorites with a complex history of intrusion and metamorphism (Dibblee, 1982). The northwest portion of the San Gabriel Valley, in the vicinity of the JPL site, is composed of roughly 1,500 to 2,000 feet of Cenozoic alluvial-fan deposits that unconformably overlie the crystalline basement complex exposed in the San Gabriel Mountains (Smith, 1986). These alluvial deposits typically consist of poorly-sorted coarse-grained sands and gravels, with some finer sand and silty material. Clasts within the alluvial deposits range from silt-size to boulders over 3 feet in diameter.

Periodic tectonic uplift of the San Gabriel Mountains has occurred during the past 1 to 2 million years producing the present topography of the area (Smith, 1986). Most of this uplift has occurred along north- to northeast-dipping reverse and thrust faults located along the south to southwest edges of the San Gabriel Mountains. This system of faults along the southern edge of the San Gabriel Mountains is referred to as the Sierra Madre Fault system. The Sierra Madre Fault system separates the San Gabriel Mountains to the north from the San Gabriel Valley to the south.

2.1.4 Regional Hydrogeology

The San Gabriel Valley contains distinct groundwater basins, including the Raymond Basin where JPL is located. The Raymond Basin is bordered on the north by the San Gabriel Mountains, on the west by the San Rafael Hills, and on the south and east by the Raymond Fault. The Raymond Basin provides an important source of potable groundwater for many communities in the area including Pasadena, La Canada-Flintridge, San Marino, Sierra Madre, Altadena, Alhambra, and Arcadia. JPL is located in the northwest portion of the Raymond (Groundwater) Basin.

In the Raymond Basin, alluvial deposits derived from the San Gabriel Mountains contain virtually all of the groundwater produced in this region. A review of the geology of the Raymond Basin indicates that the predominant materials present in the basin are the crystalline basement rocks, the Older Alluvium and the Younger Alluvium as illustrated in Figures 2-1 and 2-2. Because of the crystalline nature of the basement complex, groundwater occurs only in joints and fractures in the basement rocks, and, owing to the low porosity in the basement complex, this unit is considered nonwater-bearing.

Throughout the Raymond Basin, groundwater flows in different directions depending on the exact location in the basin. In the northwestern portion of the Raymond Basin, groundwater flow is generally southeast. However, JPL is located near the extreme northern edge of the basin where a confluence of groundwater flow regimes occurs. West of JPL, the groundwater flow is predominantly to the southeast, and east of JPL the groundwater flow is predominantly to the south-southwest.

Located within the Raymond Basin are several water-spreading grounds and municipal water production wells. The presence of the spreading grounds and production wells locally influence the configuration of the water table beneath JPL. A detailed discussion of the groundwater beneath JPL is presented within the OU-1/OU-3 RI/FS report that summarizes the results of the groundwater investigation at JPL (FWENC, 1999).

2.2 LOCAL SETTING

Discussions in following subsections include the local meteorology, local topography, local geology, and local hydrogeology as they relate to JPL.

2.2.1 Local Topography

JPL is located at the southern base of the San Gabriel Mountains. The northernmost portion of the site consists of Gould Mesa, a flat-topped southern promontory of the San Gabriel Mountains that rises 300 feet above the main area of the JPL complex. The remainder of the site is moderately sloped, and has been graded extensively throughout its development. The JPL facility varies in elevation from approximately 1,070 to 1,550 above mean sea level. A topographic map including JPL and surrounding areas is presented in Figure 2-3.

The entire JPL site drains, via storm drains and surface runoff, into the Arroyo Seco. In addition, storm runoff from parts of La Canada mingles with that of JPL prior to discharge to the Arroyo. The ground surface elevations at JPL are higher than the Arroyo Seco flood plain elevation of 1,070 feet.

The main facility occupies approximately one-half of a square mile of the less steeply sloping terrain beneath Gould Mesa from approximately 1,250 to 1,070 feet above mean sea level. As a result, much of the ground surface between 1250 and 1070 feet is covered with buildings, pavement, or other structures. In fact, the buildings and pavement associated with the main facility cover an estimated 85 to 90 percent of the ground surface between 1250 and 1070 feet.

2.2.2 Local Meteorology

Rainfall in the vicinity of JPL is higher than for the City of Los Angeles, averaging about 20 inches per year. The higher amount of rainfall near JPL results from the orographic effects generated along the southern slope of the San Gabriel Mountains. As with the remainder of the greater Los Angeles metropolitan area, the majority of the annual precipitation (roughly 80 percent) occurs between November through April.

Temperatures at JPL are relatively mild, with August typically the warmest month and January the coolest. The minimum recorded mean monthly temperature in the JPL area was 32.5°F in January 1937 and the maximum mean monthly temperature was 95.5°F in August of 1929 (CDM, 1990).

Similar to the Los Angeles region, wind patterns around JPL change seasonally in both strength and direction, in response to the normal variations in barometric pressure systems. Generally, winds are mild throughout the year, characterized by breezes from the ocean (onshore) during the day and land breezes (offshore) at night.

Also similar to the Los Angeles region, JPL is occasionally affected by "Santa Ana" winds during the fall. Winds resulting from Santa Ana conditions have resulted in wind speeds over 100 miles per hour (mph) down the Arroyo Seco (Boyle Engineering, 1988).

2.2.3 Local Geology

Along the northern edge of the Raymond Basin, part of the Sierra Madre Fault system, the system that separates the uplifted San Gabriel Mountains from the San Gabriel Valley, crosses JPL. West of JPL, the main range-front fault has been named the Mt. Lukens Thrust Fault (Figure 2-4). East of JPL the main range-front fault is identified as the south branch of the San Gabriel Thrust Fault, the main range-front fault crossing JPL is called the JPL Thrust Fault (also known as the "bridge fault").

The inferred location of the JPL Thrust Fault as it crosses JPL is shown in Figure 2-2. In 1977, Agbabian Associates completed a seismic study of JPL and mapped the JPL Thrust Fault. Included in Figure 2-5 are the traces of the JPL Thrust Fault behind Building 150 as mapped by Agbabian Associates (1977) and as previously mapped by Converse and others (1971). During the Expanded Site Inspection of JPL completed in 1990 (Ebasco, 1990a), Ebasco geologists performed a reconnaissance survey of the surface exposures of the JPL Fault and confirmed its presence where it is exposed. Ebasco geologists also concluded that the general geometry of the fault trace more closely resembled that as mapped by Agbabian Associates, although Ebasco could not confirm the locations of the two small normal faults mapped by Agbabian Associates.

Traces of the normal faults may have been obscured by the thick natural vegetation currently growing on the hillside.

Ebasco geologists also field checked and confirmed the location of the JPL Thrust Fault exposed near Building 98 and former Building 134 west of the bridge across the Arroyo Seco. At this location, the trace of the JPL Thrust Fault can be found at the contact between granitic alluvium at the foot of the hill behind JPL and the crystalline basement (diorite at this location) above it. In general, the exact trace of most of the JPL Thrust Fault and its associated branch is not known, but the fault appears to be a north-dipping (approximately 40 degrees) reverse fault which commonly places the crystalline basement complex over Older Alluvium.

On the north side of the main branch of the JPL Thrust Fault, behind building 150, three shallow wells were installed as part of a soil dewatering system (Crandall and others, 1981). During the drilling of these wells, crystalline basement rocks were reached from 2 to 20 feet below grade. This indicates that very little alluvium is present in this area north of the main branch of the fault. Just south of the JPL Thrust Fault, monitoring well MW-7 was installed to 275 feet (Ebasco, 1990a) and never reached basement rock. However, some nearby City of Pasadena municipal production wells and two of the deep monitoring wells installed at JPL have reached basement south of the JPL Thrust Fault between 550 feet and 725 feet below grade.

2.2.3.1 Stratigraphy

The stratigraphy beneath the JPL study area was evaluated by a review of published geologic maps and by subsurface information obtained during the course of the OU-2 and OU-1/OU-3 Remedial Investigations. The JPL site lies within the geologic map of the north half of the Pasadena Quadrangle, produced by the California Division of Mines and Geology (Smith, 1986). Descriptions of the lithologic formations found beneath the study area, as described by Smith (1986), are presented below, beginning with the oldest unit in the area. The surface expressions of these rock and soil types in the JPL area are presented in Figure 2-2.

Leucocratic Granodiorite (gl)

The oldest rocks in the subject area include igneous intrusive rocks that comprise the crystalline basement complex beneath the subject area (Figure 2-2). The dominant crystalline rock type is a light gray to buff, fine to medium grained leucocratic granodiorite (map unit gl) with a hypidiomorphic texture (Smith, 1986). Its typical composition is: plagioclase, 60 percent to 75 percent; potassium-feldspar, 5 percent to 15 percent; quartz, 10 percent to 15 percent; biotite, 2 percent to 10 percent, and a trace of magnetite. This rock type is widely distributed and recognized by its light color and resistance to chemical weathering. The age of this rock is probably Cretaceous (Smith, 1986).

Saugus Formation (TQs)

The Saugus Formation (map unit TQs) lies on top of the crystalline basement rocks at the far eastern edge of the JPL study area (Figure 2-2). It is typically composed of arkosic sand, pebbly arkosic sand, and conglomeratic arkosic sand that range from light-brown to light-gray in color. Lithic clasts in the Saugus Formation were likely derived from the granitic and metamorphic terrain located in the adjacent San Gabriel Mountains. However, some easily recognizable and distinctive clasts of monzonite and augen gneiss, are abundant in all of the sedimentary units younger than the Saugus Formation, but are found in the Saugus (Smith, 1986). The formation appears to have been deposited primarily in a fluvial floodplain environment (Smith, 1986). This is in contrast to "high energy" fanglomerate depositional environment that exists today along the southern edge of the San Gabriel Mountains. However, the clast sizes and bedding styles of the Saugus Formation are sufficiently variable to indicate a range of depositional environments (Smith, 1986).

The age of the Saugus Formation is uncertain, as no fossil evidence has been found in this area. However, the formation may be late pliocene to early pleistocene in age, based on comparison to similar deposits in the Ventura basin that contain fossils of that age (Smith, 1986).

The three principal criteria that can be used to identify the Saugus Formation include (1) the combination of lithic clast types in the Saugus Formation is different from that of younger units, (2) the Saugus beds are typically not as well graded as those of younger units, and (3) the Saugus beds have generally resulted from a relatively low energy floodplain depositional environment compared to younger formations (Smith, 1986).

Pacoima Formation (Qp)

The Pacoima Formation (Map unit Qp) lies unconformably on the crystalline basement complex beneath most of the JPL study area and on the Saugus Formation at the far eastern edge of the study area. This unit is typically composed of fluvial conglomeratic arkosic sand that contains significant amounts of gravel and some boulders. Its color is light brown where unaffected by weathering, but can range from orange to dark reddish-orange with significant weathering.

The gravel and boulders in the Pacoima Formation are generally of the same lithology as the basement rock types that are found in the adjacent San Gabriel Mountains. In a general sense, the Pacoima lithic clast assemblage is identical to that of the modern stream deposits that emerge from the San Gabriel Mountains (Smith, 1986). The Pacoima Formation was likely deposited in a fanglomeratic to stream channel type environment (Smith, 1986) that is generally assumed to have had a higher energy than the environment in which the older Saugus Formation formed (Smith, 1986).

The greatest exposed stratigraphic thickness of the Pacoima Formation is approximately 300 feet on the east side of Gould Mesa, approximately 1 mile north of JPL (Smith, 1986). There, a continuous section is exposed from the bottom of the Arroyo Seco Canyon to the top of the mesa. Beneath the subject area, it is estimated that the Pacoima Formation is approximately 200

Continue

to 300 feet thick. The Pacoima Formation does not differ lithologically much from younger strata, making distinction between them difficult. The easiest way to differentiate the Pacoima Formation from younger units in surface exposures is the characteristic way the Pacoima Formation weathers to a red or orange color (Smith, 1986).

Older Fanglomerate Series (Qo1 to Qo4)

Overlying the Pacoima Formation throughout the study area is the Older Fanglomerate Series (map units Qo1 to Qo4). This series is composed of light-brown to gray to dark-brown fluvial arkosic sands with abundant gravel and boulders. Smith (1986) divided the series into four stratigraphic members, in a somewhat arbitrary manner, on the basis of apparent age. Overall, there are no local compositional differences between the oldest (Qo1) and youngest strata (Qo4) within this series. The predominant source of the Older Fanglomerate series is clearly the crystalline rock complex exposed in the present day San Gabriel Mountains, although some reworked material from the Pacoima Formation is found in these sediments (Smith, 1986).

The maximum exposed thickness of the Older Fanglomerate Series is about 150 feet along the east side of the Arroyo Seco near JPL (Smith, 1986). The age of this series ranges from late Pleistocene through Holocene. The age of the oldest strata is not precisely known because no fossil evidence has been found (Smith, 1986).

Recent Fanglomerate and Stream Channel Deposits (Qr and Qsc)

The Recent Fanglomerate (map symbol Qr) mapped in the subject area is material of Holocene age that is present on alluvial fan surfaces still subject to deposition (Smith, 1986). Stream Channel Deposits (map symbol Qsc) represent material within confined water courses that is subject to present day reworking by stream action (Smith, 1986). The lithologic characteristics of these deposits are essentially the same as those of the youngest of the Older Fanglomerate Series (Qo4) described above.

Artificial Fill (af)

The mapping of artificial fill (map symbol af) in the area of JPL (Smith, 1986) is restricted to fills of significant size or unusual occurrence.

2.2.3.2 Soils

Several different soil types were encountered during the drilling and excavation activities at JPL. Detailed lithologic logs of the soil in each of the soil borings and soil-vapor wells drilled during the OU-2 RI are provided in Appendix A. Soils that constitute the unsaturated zone beneath JPL are composed of sediments from the Quartenary Older Fanglomerate Series described by Smith (1986). Overall, they predominantly consist of medium- to coarse-grained sand and gravel, interbedded with some fine sand and silt. Classifications of these soil types, based on the Unified Soil Classification System (USCS) (see Section 3.0, Figure 3-5), range from fine-grained silt (ML) to poorly-graded sand (SP) to coarse, sandy gravel (GP).